The Way of a Ship

LAWRENCE COUNSELMAN WROTH (1884–1970)

The Way of a Ship

An Essay on the Literature of Navigation Science

ALONG WITH

Some American Contributions to the Art of Navigation 1519–1802

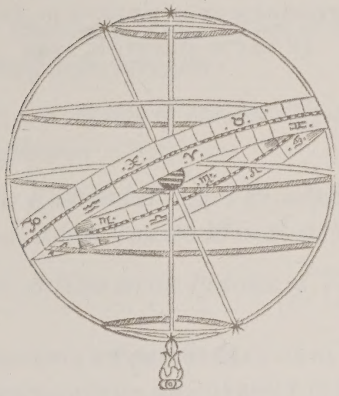
Lawrence C. Wroth

Revised versions, edited with a foreword by

JOHN B. HATTENDORF

ERNEST J. KING PROFESSOR OF MARITIME HISTORY

U.S. NAVAL WAR COLLEGE



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FOREWORD

JOHN B. HATTENDORF

AMONG his many contributions to scholarship, Lawrence Counselman Wroth was one of the pioneer figures for the study of maritime history in America. In his position as Librarian of the John Carter Brown Library at Brown University from 1923 to 1957, Wroth did much to promote an understanding of maritime history. Among his many publications, several key works touch on this subject: *The Way of a Ship* (1937), *Early Cartography of the Pacific* (1944), *Some American Contributions to the Art of Navigation* (1947); and his final work, *The Voyages of Giovanni da Verrazanno* (1970). Of these, *The Way of a Ship* and *Some American Contributions to the Art of Navigation* have long been recognized as classic contributions, but have been out of print and unavailable. Both are closely connected in their approach and have their origin in exhibitions at the John Carter Brown Library.

For more than seventy years, *The Way of a Ship* has been particularly admired for its graceful brevity in dealing with a very complex topic in maritime history and the history of science and technology. As Robert Foulke wrote in 1996, this little "unpretentious essay, in the old fashioned sense of that word, ... served as an authoritative, compact annotated bibliography, a compass laying down courses to ... thousands of volumes."[1] For many scholars over the decades, Wroth's volume has served that purpose and it has even served as a beacon for collectors, such as Henry C. Taylor, who used it as a guide to develop the magnificent collection of books on the history of navigation that he eventually bequeathed to Yale University.[2]

1. Robert Foulke, "The Way of a Ship," in *I Found it at the JCB: Scholars and Sources. Published on the Occasion of the Sesquicentennial Celebration of the Founding of the John Carter Brown Library* (Providence, R.I.: John Carter Brown Library, 1996), p. 140.

2. Lawrence C. Wroth, "Foreword," and Henry C. Taylor, "Preface" to John S.

The Way of a Ship seems to have had its origin in an exhibition that Lawrence Wroth mounted in the John Carter Brown Library's cases in September and October 1930 on navigation and maps. That exhibit, in its turn, may have derived from the introduction that Wroth had written for a facsimile edition of *Libretto de tutta la navigatione de Re de Spagna* that Wroth had published in 1929.[3] He had apparently worked on a draft of the book for a number of years. Finally, in the spring of 1937, he wrote to John Nicholas Brown:

> It has been a long time since I told you that I would like to have you look at my proposed little book on navigational science, but I have at last made a fresh draft of the manuscript and placed in some additional material. I hope that you will have time to look at it.... It will not take you long to see that this essay was written from the standpoint of the bookman, not of the practical navigator or the mathematician. It has grown out of a short article which was inspired by an exhibition of navigational books I put on in the library a good many years ago. The numerous additions made to it since have brought it almost to book size. Sometimes I feel that it shows signs of having grown in this fashion rather than of having been properly planned.[4]

By the end of 1937, The Southworth-Anthoensen Press of Portland, Maine, had published the completed work.

The idea for a new and expanded version came only slowly. It was first formally suggested by the New York publisher, W. W. Norton & Co. In April 1950, Robert E. Farlow of W. W. Norton wrote to Lawrence Wroth:

Kebabian, compiler, *The Henry C. Taylor Collection.* (New Haven, Conn.: Yale University Library, 1971), pp. vii–ix.

3. Lawrence C. Wroth, "Introduction," in *Libretto de tutta la navigatione de Re de Spagna ... Venice, 1504. A Facsimile from the Only Known Perfect Copy, now in the John Carter Brown Library.* (Paris: Librairie Ancienne Honoré Champion. Éditeur, 1929).

4. John Carter Brown Library Correspondence, 1936–1937, Box A–C: folder "Brown, John Nicholas" Wroth to John Nicholas Brown, 13 March 1937.

> I am writing to you again about my favorite book, THE WAY OF A SHIP. As you may recall, we suggested that you might care to expand this into a full-fledged book sometime, but that did not seem to be in line with your plans. It has occurred to us after reading the book again that it might be appropriate to suggest that we reissue it for a wider audience than it originally had. So I am suggesting this to you for your reaction. If the idea seems a good one, perhaps you would think of doing a preface for a so-called trade edition.[5]

In response, Wroth wrote a few weeks later,

> I am very much interested in your suggestion that you reprint *The Way of a Ship* in a trade edition. Mr. Anthoensen has never said anything about bringing out another edition of the book, and I am inclined to think that perhaps he does not want to take over any publishing responsibilities in view of the considerable increase in his printing business in the past few years....
>
> Although I adhere to my earlier decision against expanding the book into a full-sized work, yet I feel that a revision of it is quite necessary. I have learned quite a lot in the intervening years, and there are a number of slips I should want to correct, a number of things I should express differently, and a few small additions I should like to make. There would be some small expansion, but it would be my idea to keep the book down very much to its present size.[6]

Clearly, his plan was not to change it dramatically, but to retain it as a short work, to reorganize the material into a more logical sequence, and to make some explanatory additions about navigational methods linked to the development of the art of navigation. He had made significant progress with this approach, when he learned that Alan Villiers was about to publish his book with the identical title, *The Way of a Ship*, in 1953, but on an entirely different topic: sailing square-rigged vessels in the 20th century. After Villiers's book came out, the well-known author of books on

5. *Loc cit.*, 1949–50: Robert Farlow, Norton & Co., to Wroth, 21 April 1950.
6. *Loc cit.*, Wroth to Farlow, Norton & Co., 8 May 1950.

sailing, Harold A. Calahan, wrote to Wroth in December 1953: "I see Villiers has stolen your title. It is too bad that titles cannot be covered by copyright." To which Wroth replied:

> Thank you for your note about Villiers's use of my Way of a Ship title. I protested to the publisher before publication and received from them a very weak defense of themselves. Nothing could be done, however, because the words are drawn from the Bible,[7] and everyone, I suppose, is entitled to make use of Bible quotations. Even the devil, we are told, can quote scripture to his own ends. In the meantime I am going on with the revision of my own Way of a Ship in the belief that because of the very great difference in the character and subject matter of the books the conflict will not matter very much.[8]

Wroth continued his work and was actively working on it as late as July 1954, when he made several large additions before laying his work aside. The record is not clear as to why he stopped his own work. Possibly, he may have learned of two important full-length studies that would soon appear: E. G. R. Taylor's, *The Haven-Finding Art* (1957) and D. W. Waters, *Art of Navigation* (1958). Nevertheless, knowledgeable scholars have remained aware of the fact that, despite these new works, there was still nothing available that explained the subject so clearly and so succinctly as Wroth had done.[9]

Rather than to merely print the original edition of *The Way of a Ship*, I have attempted to piece together Wroth's handwritten notes and his manuscript corrections on the first printed edition to try to produce something that represents the revision that he had in mind in the mid-1950s. Since Wroth left it unfinished, this is

7. Proverbs, 30:19

8. *Loc cit.*, 1953–1954: Lawrence Wroth to H. A. Calahan, 20 January 1954.

9. John Carter Brown Library. Papers of Lawrence Wroth. Box labeled: "LCW copy of *Way of a Ship* with his projected revisions." Letter from Jeannette D. Black, Acting Librarian, John Carter Brown Library, to Mrs. Anne Klein, 28 April 1972.

not an easy task. Some of the manuscript materials are reading and research notes and were never meant as text for the booklet. Others of his surviving notes suggest additional material that he considered adding, but did not write up. I have not attempted to fill in his plan, but have limited myself to utilizing the corrections and changes to the 1937 text with the paragraphs and sections he had drafted in his own hand for the new version.

I have found only a few changes or corrections that Wroth intended for his 1947 study, *Some American Contributions to the Art of Navigation,* so this text is nearly identical to the original. However, in the case of both works, I have made a very limited number of editorial insertions in the footnotes, between square brackets, to suggest some of the more recent scholarly literature than the specific items that Wroth cited as the most authoritative sources at the time he wrote. At the same time, I have not made any attempt to alter his text or his conclusions, but I have tried to preserve his understanding of the subject and the viewpoints he so clearly expressed.

Published together for the first time, these two works remind us of Lawrence Wroth's role as a maritime historian. Forty years after the author's death, they still retain usefulness as contributions to the history of nautical science. At the same time, these essays also remind us of the continuing importance of the John Carter Brown Library as a key depository for research in the history of nautical science, one of the several sub-specialties within the broader field of maritime history that is devoted to understanding mankind's multiple relationships with the seas and oceans of the world.

Some Suggestions for Further Reading and Reference

THOMAS R. ADAMS and DAVID W. WATERS, compilers. *English Maritime Books Printed before 1801: Relating to Ships, Their Construction and Their Operation at Sea, Including Articles in the* Philosophical Transactions of the Royal Society *and the* Transactions of the American Philosophical Society. (Providence, R.I.: The John

Carter Brown Library, and Greenwich, England: The National Maritime Museum, 1995).

Selected volumes from THE MARITIME SERIES, John B. Hattendorf, series editor, published by Scholars' Facsimiles & Reprints for the John Carter Brown Library, 1992–1997:

- ALVISE CÀ DA MOSTO, *Questa e una opera necessaria a tutti li naviga[n]ti* (1490), Together with PIETRO MARTIRE D'ANGHIERA, *Libretto de tutta la navigatione de Re de Spagna* (1504). Facsimile Reproductions with an introduction by Felipe Fernández-Armesto.
- FRANCISCO FALEIRO. *Tratado del esphera y del arte del marear* (1535). Facsimile Reproduction with an introduction by Timothy Coates.
- GEMMA FRISIUS. *De principiis astronomiae & cosmographiae* (1553). Facsimile Reproduction with an introduction by C. A. Davids.
- PEDRO DE MEDINA. *L'art de naviguer* (1554). Facsimile Reproduction with an introduction by Carla Rahn Phillips.
- MARTÍN CORTÉS. *The Arte of Navigation* (1561). Facsimile Reproduction with an introduction by D. W. Waters.
- JEAN TAISNIER. *A Very Necessarie and Profitable Booke Concerning Navigation. Translated by Richard Eden* (1579?). Facsimile Reproduction with an introduction by John Parker.
- JOHN DAVIS. *The Seamans Secrets* (1594). Facsimile Reproduction with an introduction by A. N. Ryan.
- ISAAC VOSSIUS. *A Treatise Concerning the Motion of the Seas and the Winds* (1677) together with *De motu marium et ventorum* (1663). Facsimile Reproductions with an introduction by Margaret Deacon.
- JOHN SELLER. *Practical Navigation* (1680). Facsimile Reproduction with an introduction by Michael Richey.

JOHN B. HATTENDORF. *"The Boundless Deep..." The European Conquest of the Oceans, 1450–1840. Catalogue of an Exhibition of Rare*

Books, Maps, Charts, Prints, and Manuscripts Relating to Maritime History from the John Carter Brown Library. (Providence, R.I.: The John Carter Brown Library, 2003).

Danial Elliott with Everett C. Wilkie, Jr., and Richard Ring, compilers. *Maritime History: A Hand-List of the Collection in the John Carter Brown Library* (1474 to ca. 1860). Revised Edition. (Providence, R.I.: The John Carter Brown Library, 2005).

John B. Hattendorf, editor-in-chief. *The Oxford Encyclopedia of Maritime History.* (Oxford and New York: The Oxford University Press, 2007). See in particular, the following articles, each of which touch on a topic raised in these essays by Lawrence Wroth and summarize the state of scholarly understanding at the time of publication, additionally providing a further list of scholarly references:

- Astronomers and Cosmographers.
- Cartography.
- Coastal Navigation.
- Dead Reckoning.
- Hydrographical Departments.
- Logs and Ships' Journals.
- Longitude Finding.
- Longitude, Institutes of.
- Magnetism: Geomagnetism and Ships' Magnetism.
- Nautical Astronomy and Celestial Navigation.
- Navigational Instruments.
- Navigational Manuals.
- Navigators.
- Observatories.
- Prime Meridians.
- Sailing Directions.
- Western Navigation.

ACKNOWLEDGEMENTS

I AM particularly grateful to Rick Ring, formerly of the John Carter Brown Library staff and most recently at Trinity College, Hartford, for his great interest and encouragement for this project, particularly in providing me transcriptions of materials in the Library's archives and from the Lawrence Wroth Papers as he researched his own study of Lawrence Wroth, as well as providing invaluable assistance in facilitating the procurement of modern digital images of the illustrations in this volume.

First, I thank Dr. Norman Fiering and Dr. Edward Widmer, as successive directors of the John Carter Brown Library, who provided much encouragement for me in this project. In addition, I thank Susan Danforth, who helped locate some hard-to-find images, and Susan Newbury, who carefully copy-edited the text, and Heather Jespersen and Leslie Tobias-Olsen, who provided assistance in digitizing the images from the John Carter Brown Library collection. I am grateful to Colonial Williamsburg for providing the image of the Hubard document.

In particular, I thank Mark Argetsinger for his work in creating the layout, design, and typesetting for this edition.

JOHN B. HATTENDORF
Newport, Rhode Island
November 2010

PART I

The Way of a Ship

An Essay on the Literature of Navigation Science

Was hilfft der wechter in der ſtatt/
Dem geweltigen ſchiff im meer ſein fart/
So ſie Gott beyde nicht bewart.

Ich

PREFACE*

THIS ESSAY grew out of an exhibition of books on navigation science which, some years ago, its author arranged at the John Carter Brown Library. The innumerable questions which presented themselves to him at that time, questions that had to do with the selection of materials from the Library's rich collections and with the writing of descriptive labels for the books and maps chosen for display, sent him for information to many general and special works of reference. It will suffice to mention only the chief of these.

BENSAÚDE, JOAQUIM. *Historie de la science nautique portugaise.*

(This is the general title of a series numbering five separate studies and eight facsimiles of books on navigation, published by order of the Portuguese government, among them *L'Astronomie nautique au Portugal à l'époque des grandes découvertes*, Bern, 1912. This separate study and the editor's *Résumé* of the whole body of material, bearing the same title as the series title above, published at Geneva in 1917, together with his introduction to the *Regimento do estrolabio* [Volume I of the facsimiles] are outstanding discussions of the history of early navigation science.)

IMAGE OPPOSITE: A woodcut from the *Warhaftige Historia und Beschreibung eyner Landtschafft ... in der Newenwelt America*, of Hans Staden, published in Marburg in 1557, portrays mariners using both astrolabe and cross-staff. It is unnecessary to say that the celestial phenomenon of sun, moon, and stars showing high in the heavens at the same moment is unlikely to have occurred even in the course of Hans Staden's remarkable adventures in Brazil, but the picture nevertheless demonstrates two important processes in navigation practice spoken of in our text, that is, the use of the cross-staff in the measurement of lunar distances, and of the astrolabe in determining the altitude of the sun. *John Carter Brown Library.*

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* Originally published 1937, by the Southwark-Anthoenson Press, Portland, Maine. The original edition was dedicated "To Lawrence Kinvin Wroth."

Deetz, Charles H., and Oscar S. Adams. *Elements of Map Projection.* [Department of Commerce, U.S. Coast and Geodetic Survey, Serial No. 146.] Washington, D.C., 1931.

(A simply presented, but illuminating study of the general subject of map projections.)

Fontoura da Costa, A. *A Marinharia dos descobrimentos.* Lisbon, 1933.

(A bibliography and an analysis of the subject of the early books and implements of navigation.)

Gernez, D. "The Works of Lucas Janszoon Wagenaer," in *The Mariner's Mirror*, for July, 1937.

Gould, Rupert T. *The Marine Chronometer, its History and Development.* London, 1976.

(This is the full story of the instrument which solved the problem of longitude, and a historical outline of the problem itself. In a later article "John Harrison and his Time-keepers," *The Mariner's Mirror* [The Quarterly Journal of the Society for Nautical Research] for April, 1935, Lieutenant-Commander Gould retold the story, more specifically as it related to Harrison.)

Hakluyt Society. Works Issued by the Hakluyt Society. London, 1847 to present.

(In the texts, introductions, and appendices of many numbers of this great series are numerous discussions, lists, and documents of great interest in the study of navigation history.)

Heaton, Herbert. *Economic History of Europe.* New York, 1936.

(Contains several passages of interest on the navigation practices of the Vikings.)

Manuel II, King of Portugal. *Early Portuguese Books 1489–1600 in the Library of His Majesty the King of Portugal.* 3 v. 1929–1935 (text in English and Portuguese).

(This bibliography by King Manuel, with numerous references to contemporary and earlier literature, is especially valuable for its accounts of the works of Abraham Zacuto, Pedro Nunes, and other Portuguese writers on navigation.)

MARKHAM, ALBERT HASTINGS, editor. *The Voyages and Works of John Davis the Navigator.* Publications of the Hakluyt Society, No. LIX. London, 1880.

(Appendix A, pages 339–366, contains an important list of works on navigation, previous to and during the age of Elizabeth, with comment by the editor.)

MEIGS, JOHN FORSYTH. *The Story of the Seaman.* 2 v. Philadelphia, Pa., and London, 1924.

(A most interesting storehouse, not always perfectly ordered, of quotation, professional comment and opinion on ships and navigation.)

NORDENSKIÖLD, A.E. *Facsimile-Atlas to the Early History of Cartography with Reproductions of the Most Important Maps Printed in the XV and XVI Centuries.* Translated from the Swedish Original by John Adolf Ekelöf and Clements R. Markham. Stockholm, 1889.

(Book of great learning, admirably and systematically presented, and indispensable, not only to the study of maps, but to a knowledge of navigation implements and practices as a whole.)

STEVENSON, EDWARD LUTHER. *Portolan Charts their Origin and Characteristics with a Descriptive List of Those Belonging to the Hispanic Society of America....* New York, 1911.

(An introduction to the fascinating subject of medieval and later maps.)

Many friends, so many that the author cannot very well name all of them here, have helped by directing his attention to valuable material, or by criticizing his manuscript and proofs. In this connection, however, he feels that he must mention the late William E. Foster, Benjamin C. Clough, Howard M. Chapin, John Nicholas Brown, and Raymond Clare Archibald, of Providence; Horace Reynolds, of Cambridge, Massachusetts; William Davis Miller, of Wakefield, Rhode Island; Harry Miller Lyndenberg, of New York, and Henry R. Wagner, of San Marino, California.

E.P. Goldschmidt, of London, informed him of the Bamberg broadside in which appears the earliest printed representation of a cross-staff. To these and many more the author, who is neither seaman nor scientist, but a landlubber and a bookman, deeply interested in the lore and traditions of the sea, expresses his gratitude for aid and encouragement.

LAWRENCE C. WROTH

The John Carter Brown Library
15 September 1937

INTRODUCTION

"THERE be three things," said the wise King, "which are too wonderful for me, yea, four which I know not: the way of an eagle in the air; the way of a serpent upon a rock; the way of a ship in the midst of the sea; and the way of a man with a maid."

In the three thousand years that have passed since this admission of ignorance was made we have learned something of the way of an eagle in the air by the successful attempts men have made to imitate his flight. The modern ophidologist can tell us many things about the serpent's way in his stony retreat. Of the way of a man with a maid, however, science has taught us nothing. And what a gesture of humility it was that Solomon should profess ignorance of that particular procedure! Adept in matrimony, celebrated in song and legend for his thousand conjugal associations, lover of "many strange women ... women of the Moabites, Ammonites, Edomites, Zidonians and Hittites," this most experienced man of the centuries still must stand in question before the mystery of that relationship. We, too, leave that problem unsolved, and humbly address ourselves to the much simpler business of the way of a ship in the midst of the sea.

When Solomon put an understanding of ship ways in the category of things too wonderful for him, he was thinking certainly of those vessels in which Hiram, king of Tyre, the great Phoenician, conducted the carrying trade of that ancient world. These friendly princes were in many enterprises together. "The king," we are told, "had at sea a navy of Tharshish with the navy of Hiram: once in three years came the navy of Tharshish, bringing gold, and silver, ivory and apes, and peacocks." Certain pillars of the Temple were fashioned of almug trees brought from Ophir to Palestine in Hiram's ships by way of the Red Sea. And into the Temple went also great cedars carried down from Lebanon to the

coast by Hiram's men, and taken thence on their barges to the appointed place. In addition to his employment of the Phoenicians for these purposes and his sharing with them the western trade of Tharshish, Solomon ventured in another direction on his own account. He built him a navy in the land of Edom on the shore of the Red Sea, "and Hiram sent in the navy his servants, shipmen that had knowledge of the sea, with the servants of Solomon. And they came to Ophir, and fetched thence gold, four hundred and twenty talents, and brought it to King Solomon." Many dealings with the sea had Solomon, and it must have been vexation to him that neither he nor his people knew the ways of ships.

It was natural enough that Solomon should find cause for wonder in all this going about in ships, for alone of his world, the Phoenicians possessed this "knowledge of the sea" necessary for a voyage from Tyre to Ophir, a region beyond the Red Sea, still unidentified; or through the Straits of Gibraltar and northward to the tin-bearing isles and to Gaul and Britain; or, finally, from Tyre to Tharshish in Spain, and from there to some far African country whence might be brought away ivory and apes and peacocks. This early navigation is wonderful for us, too, even in the amplitude of our general knowledge. What guided these men who braved "the old gray widowmaker" we know no more than King Solomon, the sleeping partner of their ventures. When the Phoenician sailors of the sixth century before Christ, sent out, according to Herodotus, by Neco, king of Egypt, sailed southward along the eastern coast of Africa, rounded the Cape of Storms, and thence made their way northward to Gibraltar and so again to Egypt, what method of navigation did they use for that two years' exploration? We do not know what aids they carried for a voyage that must often have taken them far from land, but we do know certainly that they had no mariners' compass, and that whatever charts or sailing directions they may have possessed for navigating the long-familiar Mediterranean, they could have had nothing of the sort for those unexplored stretches of African coasts and seas. We have no evi-

dence, either, that these shipmen, or their successors for hundreds of years afterwards, possessed instruments of celestial observation by which they might know even roughly their position in the open sea. They had for their direction, it is true, the sun and the eternal stars, the indispensable guides of sailors in all times, but beyond these, and good ships, discipline, and courage, the records are silent as to the navigation aids of the Phoenicians, leaving us to wonder with Solomon at this adventurer upon the great oceans, this "grave Tyrian trader" who, in the course of business, went regularly to lands known to other eastern races only in fable, who, as a matter of custom, took his ship

> Betwixt the Syrtes and soft Sicily,
> To where the Atlantic raves
> Outside the Western Straits, and unbent sails
> There, where down cloudy cliffs, through sheets of foam,
> Shy traffickers, the dark Iberians come;
> And on the beach undid his corded bales.

We leave now Solomon still perplexed by the procedure that resulted in so much comfort and splendor for him and his household, that brought him kings' daughters to stand among his honorable women, that gave him a throne of ivory overlaid with the best gold, golden drinking vessels, horses and chariots and linen from Egypt, and so much silver that it was as plentiful in Jerusalem as the very stones of the street. We leave now the ivory palaces for the harsh unfriendly seas. It is to take us three thousand years to learn to navigate a ship, and it is time to begin.

CHAPTER I

Navigation and Sea Voyages of the Ancient World

IN THAT STANZA from *The Scholar-Gipsy* which has just been quoted and in the one preceding it, Matthew Arnold made poetic reference to a development in maritime history which occurred between the time of Solomon and the earliest years of the Christian era. The preeminence upon the seas of the Phoenicians was not to endure forever. The Greek sailors, "The young light-hearted Masters of the waves" were next to have their turn as the explorers, colonizers, traders, and freighters of the ancient world. We know little in detail of their voyages; little of their ships; and less of their navigational aids. But the results of certain of their voyages have a place in the record of the world's enlargement.

In the fourth century B.C., Pytheas, a Greek of Marseilles, led from that city an expedition which passed Gibraltar and, sailing northward along the European coast, made the earliest effectual discovery of the British Isles. It may be that the Phoenician traders of Spain had been there before him, but whatever knowledge these far-sailing adventurers may have acquired of those northern coasts and the tin-bearing isles had not been shared with their rivals of the Mediterranean world. In the course of his exploration of the eastern coasts of England and Scotland, Pytheas went so far to the North that he encountered a cold and misty ocean wherein, by sight or hearsay, he learned of the land of Thule which has been variously identified in later ages as the Shetland Isles, Norway, or Iceland. As "Ultima Thule," that island has become in romantic metaphor the symbol of far places, the distant but not inaccessible goals of the physical and spiritual worlds. The voyage of Pytheas is recorded chiefly in the works of Strabo, who, drawing upon

Polybius, spoke of it briefly in several connections for the single purpose of refutation, labeling its leader "charlatan" and "juggler," and characterizing his reports as ridiculous. But greater men than he, of his own and later worlds, have accepted the Pytheas narrative as substantially true. What misfortune for us that with so many dull texts preserved through the centuries the log of the voyage of Pytheas, *The Circuit of the Earth*, should have been lost!

It was not only in the West that the Greeks measured themselves against the sea. A better documented voyage than that of Pytheas was the expedition made by Nearchus, Alexander's admiral, down the Indus and from its mouth westward and northwestward along the Asiatic shore of the Indian Ocean to the head of the Persian Gulf. And in the first century of the Christian era one Hippaelus, a Greek Mariner, boldly eschewing the traditional voyage of the traders, allowed the Southwest monsoon to carry him directly from the Arabian coast across the upper part of the Arabian Gulf to the rich ports of the Indian peninsula, the culmination, perhaps, of efforts to this end which has been in process of trial for more than a century.

Those extensive voyages of Pytheas, Nearchus, and Hippaelus, along undescribed coasts or across open waters beyond the loom of the land, stand high upon the list of achievements of the Greek spirit. We turn from them to a Mediterranean voyage of the early Christian period, not an exploration, but a workaday journey in the interests of trade and passenger transportation.

Once at Caesarea in Asia Minor it became necessary for a Roman centurion in charge of a few prisoners of state to make his way into Italy. The central figure of the group, whom we recognize as the Apostle Paul, had appealed to Caesar and to Caesar must go, however weary the road. The little company of travellers found at hand a ship of Adramyttium, and in it set forth northward, hugging the coast as was the custom of the time. After a few days' rest at Sidon, they sailed again to the north, but contrary winds drove them westward to Cyprus whence with difficulty they struggled back to

the southern coast of Asia Minor. After many days they attained Myra, a city of Lycia, just in time for the centurion to transship his prisoners and their guard to a vessel of Alexandria, then clearing for Italy. Prevented by baffling winds from passing Cnidos, the southwestern point of Asia Minor, they sailed southward to Crete instead of crossing the Aegean Sea. On making "the fair Havens," a port on the southern coast of Crete, they became uneasy to find the winter approaching and themselves so little advanced on their journey. The blessed Paul, who ceased not to prophesy throughout the voyage, counseled them to make that harbor their winter quarters, but by attempting to reach Phenice, a more commodious port westward of Fair Haven, they sailed straight into disaster. It is sad to record that when the event turned out as he had predicted the Apostle reminded the ship folk of his prescience by a particularly irritating version of "I told you so." A favorable breeze had started them on their way, but soon Euroclydon, the dreaded northeast wind, came down upon them. The ship was not able to bear up into its force and they "let her drive." She scudded before the tempest with bare masts for two weeks, and finally was driven ashore on the Island of Malta. After three months of enforced hibernation there, the company set out in another ship of Alexandria, whose sign was "Castor and Pollux." Thereafter, the itinerary was Syracuse, Rhegium, Puteoli, and so overland to Rome.

Truly this was a tedious journey which Paul was compelled to make as the result of his "Appello Caesarem," but except for the mischance of the shipwreck, one may doubt whether it differed much in kind from other long voyages of the day. There is testimony in plenty, indeed, that because of similar misadventures the sea was dreaded by the ancients. "Ye heroes," cried Teucer, "who have often suffered woes with me in the past, now banish care with wine. Tomorrow set out again upon the wide, wide sea." "Heart of oak and triple bronze had lie who first committed his frail craft to the savage sea." Thus Horace speaks in two of several expressions of fear and dread that the sea evoked from him. Sophocles has his

word: "Wonderful things there are many, and yet none more wonderful than man. This marvelous creature, driven by the stormy south wind, crosseth even the gray sea, passing half buried through the wave that would ingulf him." Sappho, as interpreted by Bliss Carman, has poured into one small cup of verse the tedium and the heartsickness of the wanderer who "weary of the foreign cities ... sea travel and the stranger peoples" laments in rich metaphor:

> So a mariner, I long for landfall,
> When a darker purple on the sea-rim,
> O'er the prow uplifted, shall be Lesbos
> and the gleaming towers of Mitylene.

In the Greek *Anthology* the sea is a shining symbol of destruction of golden youth. As a background in poetry, as a picture to be looked at comfortably from the shore, the elder races rejoiced in the sea, but to be compelled to go upon it in a ship was for them misfortune.

That clear call ringing in our ears as though uttered yesterday, the "Thalassa, Thalassa" of Xenophon's young Greeks, sprang from the throats of those weary men not through a romantic concept of the sea, but because the blue water meant escape, a pathway home, and surcease of labor. Poets have a disconcerting habit of summing up in a few lines the whole philosophy of a matter, and I conclude this excursus into the sea psychology of the ancients with a reflection from that mellow world in which men were content simply to be. Moschus tells us through Shelley's golden mouth:

> When winds that move not its calm surface sweep
> The azure sea, I love the land no more;
> The smiles of the serene and tranquil deep
> Tempt my unquiet mind.—But when the roar
> Of Ocean's gray abyss resounds, and foam
> Gathers upon the sea, and vast waves burst,
> I turn from the drear aspect to the home
> Of Earth and its deep woods, where, interspersed,

When winds blow loud, pines make sweet melody.
Whose house is some lone bark, whose toll the sea,
Whose prey the wandering fish, an evil lot
Has chosen—But I my languid limbs will fling
Beneath the plane, where the brook's murmuring
Moves the calm spirit, but disturbs it not.

These folk, it seems, knew no joy in the sea: not for them "the wheel's kick and the wind's song and the white sail's shaking," not for them salt on the lips nor "the flung spray and the blown spume, and the sea-gulls crying." Sea fever, we may believe, was not endemic along the coasts of the Mediterranean and the Aegean Seas.

There are three things essential to the comfortable navigation of the open sea: a chart to determine the course, a compass to steer by, and an instrument of astronomical observation by the use of which may be learned the latitude of the ship at fixed points of time. The equipment of a modern vessel is more infinitely complex and varied than this in the character of its aids, but except that the chronometer and radio communication from shore for the determination of positions have now become indispensable to the seaman's happiness, these three remain the basic instruments of his craft. The captain of Saint Paul's ship, whom we may consider as typical of the mariners of the later classical period, possessed no compass and, in all likelihood, no instrument for sighting the sun, moon, and stars. Centuries before his time men had devised instruments of celestial observation for use upon land, and, doubtless these would early have been adapted for use at sea if the need for their functions had been felt. Latitude, however, could not have been a matter of great concern to the pilot of a coasting vessel in the narrow Mediterranean. He went without the quadrant or the gnomon, therefore, for the good reason that he did not need them, and he contrived to get along without the compass because that instrument had not yet been conceived in the mind of man. But the chart was another matter: in coasting voyages a chart is of the

greatest utility, and its companion, the *periplus*, or book of sailing directions, is a prerequisite of comfort and safety. In some form, one must believe, these two aids to navigation were found upon the vessels of the ancient world, whether of the time of Solomon or of the good Saint Paul.

The Charts of the Ancient World

The historian of cartography encounters difficulty when he tries to determine the extent to which the mariner of Saint Paul's day, and of the time before him, made use of charts, a difficulty, it seems, somewhat naïvely set up by himself because of his failure to find references to sea charts in the literature of the ancient world. Nordenskiöld counters this objection by an analogy, remarking that though references to them seldom appear in the literature of the Middle Ages, nothing is more certain than the existence and customary use of charts and sailing directions by the mariners of that era. Furthermore, there are certain facts that must be taken account of, and facts are the proverbial straws in determining the direction of winds of argument.

When in the fifth century B.C. Herodotus was criticizing the mapmakers of his day he has before him as subject the kind of map—the "cosmos picture," it has been called—which for a long time has been the traditional form of world representation among his countrymen, and also, doubtless, among the Babylonians. No western European map of that period remains, but the conventions upon which the early Greek map was constructed survive in the so-called wheel maps or ecclesiastical maps of the Middle Ages. It is not likely that the skill and thought (disregarding the contempt of Herodotus) which went into those productions of the Greek genius would stop short when this archaic world picture had been produced. It is one of the surest facts of intellectual history, indeed, that in the first century of the Christian era, sea charts, described as the work of Marinus of Tyre, and compiled

from knowledge garnered from sailormen and travellers, were unquestionably the possession of the Mediterranean world. None of the maps of Marinus has come down to this time, but their character is known for the reason that Claudius Ptolemy of Alexandria, writing about 150 A.D., discussed them, and, as many existing manuscripts and at least one of the printed editions of his *Geographia* show, took over their system of projection for the sectional maps in his celebrated atlas.

It seems, indeed, that if one bases his negation of the existence of sea charts in the ancient world upon the fact that there are no charts of that early period remaining in actual copies, or even references to them in contemporary writing, he has solved the problem without reference to probability or to the workings of human instinct. In the study of man's progress, nothing is clearer than the fact that, generally, practices exist before they find their way into record, and if we say that the charts of Marinus were the first to be made, what we really mean is that the charts of Marinus were the earliest of sufficient excellence and of sufficient universality of use to impress themselves upon memory. Man had hardly become upright before he began to record by depiction his memory of visual experience, to draw upon the walls of his cave representations of war and the chase. The use of the pencil in its many forms to record and to depict is his natural instinct. When he began to make voyages under sail, voyages involving coasts beyond his immediate ken, it would have been natural and instinctive for him to record for future use his observation of a harbor entrance, or of a dangerous coast line, by a crude visual representation. The rude draughting of coast lines, or of profiles and ranging points of harbor entrances, the germ of the elaborate sea chart of today, is probably as old an activity as the coasting voyages of the Phoenicians.

The chart of Marinus of Tyre, according to Ptolemy's description of it, was of the kind designated broadly as the "rectangular plane chart." Its maker conceived all the geographical features of the world as inscribed upon a cylinder with the meridians throughout

their length equidistant from one another and perpendicular to the Equator. The parallels also were straight lines equidistant from one another, unrolled and flattened out. The inscribed surface would display the world represented upon a plane with a grid of parallels and meridians intersecting each other at right angles. The basic parallel of the Marinus projection was not the Equator, which lay far to the south of his world, but the parallel of Rhodes. Marinus knew that the earth was round and that as one went towards the Poles from the Equator the degrees of longitude became progressively smaller. His maps in all probability were predicated upon a ratio of 4 to 5 between a degree of longitude upon the parallel of Rhodes and a degree of longitude upon the Equator. Because all meridians, like the Equator, are great circles, the same ratio would hold between a degree of longitude upon the parallel of Rhodes and a degree of latitude upon any meridian intersecting it. Marinus kept this initial ratio constant no matter how far North or South of the parallel of Rhodes his map might extend. An area of five degrees in longitude and five degrees in latitude would, therefore, anywhere on the map, form a rectangle with its sides in a ratio of 4 to 5 with the long dimension running North and South. The "grid" of the map would be composed of rectangles so formed. Clearly a chart so constructed would be useful and moderately accurate in employment by one who sailed the Mediterranean with the parallel of Rhodes as a meridian line. Much to the North or South of that line, however, his difficulties in the use of the chart become progressively greater. But as most sailing of the first century B.C. was in the Mediterranean, we may think of the charts of Marinus as sufficient for the needs of the day in which they were made.

In a later period when, led by the Portuguese, Europeans went southward to the Equator and beyond, a form of chart was developed in which the basic parallel was the Equator itself. The makers of these charts, the portolan charts, based their projection upon the equality of a degree of longitude upon the Equator to a degree

of latitude upon any meridian that is upon any great circle. They, like Marinus, kept this ratio unchanged no matter how far to North or South the map might extend. As a consequence we recognize in their productions an equidistant and equilateral plane projection in which the components of the grid became squares rather than the rectangles of the projection of Marinus. We shall have more to say of this form of chart in a later section.

The Book of Sailing Directions

From the mariners' charts of primitive construction we turn to an examination of the sailing directions the ancient seamen carried on their voyages. The word *periplus* means a navigation, a voyage, a "sailing round." By long usage it means also a "sailing round" book, or book of harbors, distances, directions, dangers, and other matters of living interest to the mariner; it is the *portolano* of the Middle Ages, the "pilot" of our own time and place. The earliest specimen of it to descend to this age is the *Periplus of Scylax*, which has been described as having taken form sometime between the sixth and fourth centuries B.C. It is known today in the form of a twelfth-century codex found in the Bibliothèque Nationale, and its text shows evidence of having been originally composed over a period of two or three centuries through the amalgamation of numerous smaller works by many hands. Parts of it, for example, show Greek influence, while other parts, such as that which particularizes the Atlantic coast of northern Africa, display the wider knowledge of the Phoenicians of Carthage. The purpose of the work was to give the distances from harbor to harbor for the entire coast lines of the Mediterranean and Black Seas, beginning at Gibraltar and, the circuit completed, ending at the Island of Cerne in the Atlantic off the northwestern African coast. Probably the *Periplus of Scylax* was only one of many of a similar type, most of them designed for shorter stretches of coast. We know that the type exists today in the form of our own Coast Pilot, and we know,

too, that it existed in printed form and was used by sailors in the time of Columbus.

Furthermore, sometime between the day of Ptolemy and the fifth century A.D., there was compiled the book known as the *Stadiasmus*, or *Circumnavigation of the Great Sea*. The earliest remaining codex of this work is one of the tenth century in the Royal Library at Madrid. The *Stadiasmus* may be thought of as bridging the generations between the *Periplus of Scylax* and the printed work known as the *Portolano Rizo*, published at Venice in 1490. The centuries following the appearance of this first printed portolan saw the publication of many examples of the type, so that few books of our day have so long, so straight, and so well authenticated a lineage as those concise but elaborately detailed books of sailing directions, or "Pilots," found in every vessel that clears our ports. In a later chapter we shall examine the sailing directions, improved as to geographical scope and the character of the information supplied, which became available to the sailor of the Middle Ages and later periods.

In reviewing the books of sailing directions that have come down to us through thirty centuries, and in comparing them to works of the sort issued today, we are impressed by the persistence of their characteristic features. It is not only in intention that they have remained unchanged throughout those centuries but as well in their very style of expression, the simple, unaccented style in which they convey their matter to plain and trustful men. In the *Periplus of Scylax*, the earliest of them, we find, in such directions as these which follow, the form and style already set in a mould that has never changed:

> Libya begins beyond the Canopic mouth of the Nile.... The first people in Libya are the Adrymachidae. From Thonis the voyage to Pharos, a desert island (good Harbourage but no drinking-water), is 150 stadia. In Pharos are many harbours. But ships water at the Marian mere, for it is drinkable. It is a short sail from Pharos to the

mere. Here is also Chersoneses (peninsula) and harbour: the coasting thither is 200 stadia. Beyond Chersoneses is the bay of Plinthine. The mouth of the bay of Plinthine to Leuce Acte (the white beach), is a day and night's sail but sailing round by the head of the bay of Plinthine is twice as long. The shores of the bay are inhabited. From Leuce Acte to the harbour of Laodamantium is a half-day's sail. From the harbour of Laodamantium to the harbour of Paraetonium is a half-day's sail. Then comes the city of Apis. As far as this point is governed by the Egyptians.

Again in the *Stadiasmus* of the fourth or fifth century A.D., the same quality of utterance is perceived:

From Calamaeus to the Hag's Knee, 70 stadia. It is a ragged cape with a rock on the summit; on the shore there is a tree; there is anchorage, and beneath the tree there is water. Ware south wind! From the Hag's Knee to Artur is 120 stadia. This is a rugged promontory, having no anchorage, and on the promontory are two horns, stretching out like islands in the sea. Having doubled this you see the city Paraetonium.

The increase in effectiveness of the book of sailing directions by the inclusion of courses occurs without causing a change of tone, style, and general content of the matter enunciated. The *Portolano Rizo* tells the venture into the little known waters of Northern Europe:

Ireland is an island where there are many cities and lesser places. It has a circumference of about 1,280 miles. At its eastern cape opposite Miraforda [Milford] in England is a white tower ... the river Le Roxa goes up to the city of Gateford [Waterford]. The said river is wide enough at high tide for any ship to enter and go up all the way to the city which is 100 miles.

From the White Tower to the Island of Sales [Saltes] west to east is 16 miles.

Turn now to the infinitely more detailed directions of a later day and hear the same voice making its vital affirmations!

> Harbor of Refuge, lying 1 to 2 miles north-northwestward of Cape Henlopen, is formed by a breakwater which extends 1¼ miles south-southeastward from the southeast end of the Shears, and by a row of ice breakers on the Shears. The breakwater is marked 100 feet northward of its south end by Harbor of Refuge lighthouse, and at its north end by a red light. The harbor, except in its northern part, has depths of 4 to 7 fathoms, muddy bottom, for a distance of nearly 1 mile west-southwestward from the breakwater. It affords a harbor in easterly gales for deep-draft vessels. The entrance from southward is deep and clear, while that from northward across the Shears has depths of 9 to 12 feet. The deepest water, depths 5 to 7 fathoms, will be found ⅜ mile westward of the south half of the breakwater. During seasons of ice drifting ice often forms a danger.

This is an extract from the *United States Coast Pilot*, Atlantic Coast, Section C, Sandy Hook to Cape Henry, published in Washington in 1924. Every man who has cruised along a strange coast, for business or for pleasure, knows the fearful interest of the books of that series, of those modest, canvas-bound volumes that lead him into still waters at nightfall and again at dawn set him safely on his way. "I do not think," writes H. M. Tomlinson of a book of sailing directions, "this noble volume is included in the best hundred books, but I know it can release the mind from the body." But I believe no one has characterized the intention and the style of the book of sailing directions, no matter what its date or origin, better than Hilaire Belloc when he tells in one of his essays of his sure refuge from the recurrent shams and insincerities of life:

> And here, like a man discovering a diamond in blue clay, let me admit the great exception. Through all this welter of falsehood the Admiralty stands firm. I pick up my charts, I read my various 'Pilots' (especially my beloved 'English Channel Pilot I'), and the truth comes out, august, white robed, with level brows, contemptuous of advocacy. The documents of this great Department please me like the Creed. Their level voice is the voice of doom....

It is here, with the description of the book of sailing directions, that we must leave the Mediterranean sailor of the classical world, certain that he possessed this aid to navigation in the elaborate form of the *Periplus of Scylax* for a period of five hundred years preceding the Christian era. This book had been compiled as already said, by the fitting together of a great number of lesser *peripluses* made for particular stretches of coast by different men of different races, Greek, Phoenician, or Egyptian, over a long period of time, the result, perhaps, of centuries of voyaging and patient recording of observation. It seems likely from this consideration that the practice of briefly recording the features of an initial voyage, and of adding details to that record in the course of successive voyages along the same route, and thus in time forming a *periplus* for a particular stretch of coast, can be carried back without too great an assumption to the Phoenician sailors of Hiram's day. It may be that charts, made in the same way, were also in the hands of those early Phoenicians, and that aids to navigation in the form of instruments were used by them which it was not their interest to communicate to others, even to their friends. We have seen that instead of teaching the art of navigation to Solomon's men, Hiram placed in charge of his ally's vessels his own skilled mariners, "shipmen that had knowledge of the sea." Perhaps, if he had made no mystery of the aids to navigation employed by his servants on those joint expeditions, their achievements would have seemed to Solomon less like necromancy. But in that case he would hardly have needed to bewail his ignorance of ship ways, and the world might have lacked from its store the rich phrases in which he voiced his plaint.

Position Finding in the Ancient World

Even with sailing directions and charts available, the Tyrian sailor would still have been able to perform coasting voyages only. There exists no information as to any use having been made by him of

sun, moon, and stars as aids to the establishment of his position at sea. Learned men of that era knew of the declination of the sun from the Equinoctial, they had marked the movements of the moon, observed the "swing of Pleiades," and noted well the positions of certain fixed stars, especially of Polaris, the North Star, in fact and in poetry, the "lode" or "way" star. It is probable, however, that the mariner's observation of the heavenly bodies was limited to steering by them for the maintenance of direction. It has already been suggested, indeed, that not until sailors left the inland seas for broad ocean voyages would it have been necessary for them to make use of celestial observations for the determination of latitude, and that, with no need for its employment, the art of "position finding" by the heavenly bodies did not arise in this period of Mediterranean coastal journeys. But one is tempted to ask what were the means used to establish position by mariners voyaging on unknown outer coasts, or storm-driven to the open sea. The necessity of knowing their positions relative to a fixed point must often have arisen with adventurous sailors, and with this necessity recurrent in their lives they may early have adapted to their use one of those instruments, in familiar employment among astronomers on land, by means of which could be measured the angles made with the earth by Pole Star or sun. Especially could this have been true after Euclid in the third century B.C. had gathered into his Elements the unformulated geometrical conceptions of earlier ages, and spread widely among men his vision of "light anatomized," his "nothing, intricately drawn nowhere." But even if the assumption is not justified by known facts, it gives one pleasure to imagine some pilot of that old time measuring his angle with a rude quadrant, marking his position, and in sudden comprehension crying out, as Edna Millay cried out two thousand years later:

> Euclid alone has looked on Beauty bare.

But we do not know that the pilot of the ancient world possessed a quadrant, even a rude one, and we shall have no certainty of men

determining their latitude at sea for many hundreds of years after the close of the classical period.

It seems clear enough that the Phoenicians carried the art of navigation to the highest point it reached in the ancient world. Neither the Egyptians nor the Greeks made significant additions to the practices of those early pilots, nor did the Roman have anything new to say about the actual handling of ships in all the years he controlled the world. It may be that Egypt had something to give, and gave it, in the form of improvement in ship design, and that we owe, to the spread of the Roman empire the maps of Marinus of Tyre and Claudius Ptolemy, but both these things are beside our main concern. Nor did the Vikings make a contribution other than in shipbuilding, though if we are to consider the intangible values, their headlong courage must be counted as a factor in the development of navigation science. But so far as we know they had no charts, and the sailing directions evolved by them hardly deserved the name. Those collections of directions for northern voyages that found their way, much elaborated, into printed books of sixteenth-century Dutch writers seem to have had their origin in the needs of Mediterranean sailors for their "journeys to Britain and the Low Countries." The navigation methods of the Norse sailors seem, indeed, to have been of the most primitive character. But where else than in their tradition are to be found men who, without compass or chase, without means of determining latitude or longitude, customarily trusted themselves to long voyages upon the open sea. In their small, undecked vessels, making an average speed of about three miles an hour, they would load cattle and goods and set out from Norway for Iceland. In the long half-lighted days of the northern summer, they sailed slowly, haltingly, to Britain, to Iceland, to Greenland, drifting, feeling their way, lying to in storms, steering by sun and stars, sniffing the winds and watching the color of the water. Their voyages to the American coast from Greenland were carried out in this way, but those voyages and settlements were without effect because with such crude aids to

navigation as they possessed there was no assurance of ever being able to find on the next voyage the station established on this. For lack of a compass the Norse discovery of America became of no avail, but the rumor of it, tradition says, persisted to help in forming the ideas of Columbus.

CHAPTER 2

The New Era of the Middle Ages and the Renaissance

SOMETHING like a sea mist hides from our view the sailors of the Dark Ages, and lets us discern only dimly the goings and comings of their successors of the early medieval period. But as the Middle Ages draw to a close and the Renaissance approaches, the obscuring mist suddenly thins. Soon in the clear light of this freshened world, we see a new race of mariners, men who plan their voyages and handle their ships so much in the manner of our own time that, watching them, we realize the modern era in navigation practice has begun. Throughout those hidden centuries, men of the sea, unknown to us by name or race, have been inventing new things, adapting old things to new uses, or borrowing devices and methods from the peoples with whom the Crusades and the ensuing commerce with the East have brought them in contact. As we examine in detail the instruments and the methods of these Renaissance sailors, we perceive that out of the dim preceding age has emerged a new practice of the sea which is the germ of a nascent science.

The New Era Begins

As the great achievement of Columbus comes into view, we are able to particularize the vital changes that have occurred in navigation practice since we left the mariners of the ancient world hugging the shores of the land-enclosed Mediterranean, or creeping slowly along the western coast of Europe. Imperceptibly, the world has become larger; Madeira and the Azores have been

re-discovered and colonized; the Guinea Coast has been opened to trade; and Bartholomeu Dias has reached the Cape of Good Hope. From the standpoint of the mariner, the most important advance of all time has been made, for every ship of the new day carries a magnetic compass, and, through its magic, the forbidden oceans are becoming highways between the nations. Those other instruments and aids we see in the pilot's hands—the astrolabe, and the tables of the sun's quadrant declination—enable him, theoretically, to establish his latitude with relative accuracy by observation of the Pole Star or of the sun. The log, the form of which we do not see clearly, the traverse board, and the traverse tables with which he is equipped make it possible for him to approximate his longitude by the rough and ready method of "dead reckoning." The charts so carefully stowed in his cabin are fuller and more dependable than before, even though still constructed upon a projection not greatly different from that which had been employed in the classical world. With these things at hand, he is working with something like certainty and in relative comfort at the conquest of that broad ocean upon which, frustrated, he has been gazing for centuries with fear and desire.

Not the least promising sign of the new day is the interest a Portuguese prince is expressing by action in forwarding exploration and the art of navigation, for we may call it an art until, in the next century, we see it adopting the cold precision of a science. Other princes and other nations have hardly awakened to these activities. Spain is giving them scant attention, though one day her Contratactión House at Seville is to be Europe's principal school of pilotage. France is making a small contribution to their development through the excellence of the sea charts of her Provençal sailors. Soon to become less indifferent, England is showing at this time almost no interest in exploration or in the science upon which its success depends. It is an unrelated fact, it seems, that an astronomical treatise of very great utility in the beginnings of that science, the celebrated *Sphaera mundi* of Johannes de Sacrobosco,

came from the hand of a Yorkshireman, born John Holywood, of Halifax, sometime in the thirteenth century.

Henry the Navigator

The story of the Portuguese prince who never went to sea for an extended voyage, but who has been designated in later centuries as "Henry the Navigator," is one of the most familiar in the annals of nautical science. Whether the subsequent greatness of Portugal in Europe, Africa, Asia, and America had its origin in Henry's passion for exploration and the science of navigation, or whether this characteristic of the royal scholar was a prefiguring in his person of the latent imperialism of his country is a pretty question of the chicken and egg category that we may safely leave to the schoolmen. Or, we may hold a third theory of what lay beneath Prince Henry's activity. It has been said that his great ambition was to crush the Mohammedan world, and that he sought to establish communication with the Christians of Ethiopia so that in good time the Saracen and the Turk might be caught between the Christian forces of Europe and Africa. To this end, he attempted to find the way around the southern continent, unaware of its extent; to this end, his pilots went forth, exploring, studying, and recording. It was not spices that drew his nation eventually to India, it has been said, but a zealous search for the colored Christians of Prester John's fabled empire.

But whatever his motive, Henry established a school of navigation and astronomy at Sagres, the extreme southwestern point of Europe, and there, with the broad world before him, carried on what we may think of as laboratory researches with the celestial world, continents, and oceans as his media of experimentation. He sent out one expedition after another to explore the west coast of Africa, hoping always that one of his fleets would reach the mysterious cape which none of that epoch might claim to have seen. When Dias accomplished this feat in 1486, Henry had been many

years in his grave. His noble curiosity had so inspired his countrymen, however, that they had pushed on to the systematic conquest of distant seas and lands. With Vasco da Gama in India by way of the Cape of Good Hope in 1498, and Magellan's companions thereabouts by way of the Strait in 1521, Henry's zeal had found brilliant justification. Out of this mighty doing came, early in the new century, the quiet enunciation by Portuguese scholars and sailors of the enduring principles of navigation; out of it came also, in later years, Camões and the hardy rhythms of the *Lusiads* as survivors of the great voyage.

What bliss it were, if we may turn to paraphrase, to have lived in that dawn of time when in men's belief the earth was the fixed and central sphere of the Universe, a sphere surrounded and enclosed by nine separate celestial spheres or heavens all singing together to declare His glory! The ninth heaven was the *primum mobile*, the first mover, which in its daily "rush about the Earth" carries all others with it. In that ninth heaven were the celestial poles of North and South, called the poles of the world, "because they terminate the axis of the sphere and the world revolves on them."

Sacrobosco, the medieval astronomer of whom we shall have more to say, and whose picture of The Universe we have just described, tells us concisely that "the elevation of the pole of the world above the horizon is as great as the distance of the zenith from the Equator." Upon this axiom was based the practice of determining latitude by measuring the height of the pole, for the angular distance of the observer's zenith from the celestial equator is his latitude. The pole itself being an abstract point in space, it could not, of course, be seen by these watchers of the skies. What they could see was the constellation which made a daily revolution around it, *Ursa Minor,* the Little Dipper, especially its brightest star, *Polaris*, the North Star, immemorial guide of man upon land and sea. When they had learned to measure the angular height of Polaris and had charted its movements with respect to the Pole, they found it simple to calculate the elevation of the Pole above the

horizon, and thus, if a figure be allowed, to see the invisible Pole through the eye of Polaris.

Propositions and theories are rarely so simple as the bare statement of them. To determine latitude at sea or upon land it was not enough merely to measure the angle between Polaris, observer, and horizon. That initial operation must be corrected by the addition or subtraction of the distance of Polaris below or above the Pole at the time of observation. This relationship was determined by the position with regard to Polaris of the stars known as its "guards," the outermost stars in its own constellation, "Ursa Minor." By way of visualization of the problem the medieval astronomers designed a diagram portraying the figure of a man placed within a circle in which the Pole was conceived as the center of his body. At the top of the circle was his head, at the bottom, his feet; his two arms were extended horizontally to East and West. Each of the quarters of the circle thus established was subdivided by diagonal lines running from center to circumferences above and below the East and West arms. The rule derived from centuries of observation was first printed in the *Regimento do estrolabio* of 1509 in eight prescriptions. Thus we read:

(1) When the guards are in the arm of the West, the North Star is found at 1½ degrees above the Pole.

(2) When the guards are in the line below the arm of the West, the North Star is at 3½ degrees above the Pole.

And so the rule continues for the eight positions possible for the guards in their diurnal revolution around Polaris. The degrees of distance above or below the Pole thus established are the corrections to be applied to the original measurement of the height of Polaris. The observer is instructed that when the guards are found in one of the four places in which the star is above the Pole he is to subtract the correction from the angle of the height of Polaris obtained by his original observation. When the guards are found below the Pole, the degree of correction is to be added.

Thus in a simple formula we have L n = H ± C, or, the North latitude of the observer is the original observation of the height of Polaris minus or plus the correction. If a mariner measured the height of Polaris at 20° at an hour when the guards were in the West arm his latitude north would be 20° – 1½° or 18° 30′.[1] The rule for determining latitude south of the equator, when Polaris was no longer visible, was made by certain stars in the Southern Cross. That rule had to be constructed when the Portuguese expeditions began customarily to attain latitudes south of the equator.

The Mariner's Instruments of Navigation

Columbus was the heir of this awakened age. Standing as he does at the beginning of the modern era in navigation history, he becomes for us the type of the sailor of the period, and his knowledge and practice the epitome of the current practice of his time. The mariner's compass he carried could not be called upon for the exact results of a modern compass because neither he nor the more learned men of his period yet realized that the true north and the magnetic north were not the same, or realized that the variation of the needle was itself variable in the same place from year to year.

When and from what source a needle touched with magnetite, or loadstone, first came into use in navigation are questions that have not yet been answered by the historian of science. The honor of inventing the mariners' compass has been claimed for the Arabs, the Chinese, the Italians, and the Vikings, but the evidence in each case is so slim in amount and so contradictory in character that we leave the discussion with only this reference to it. It is enough to say that the north-pointing property of the magnetized needle was known long before its adaptation to use at sea,

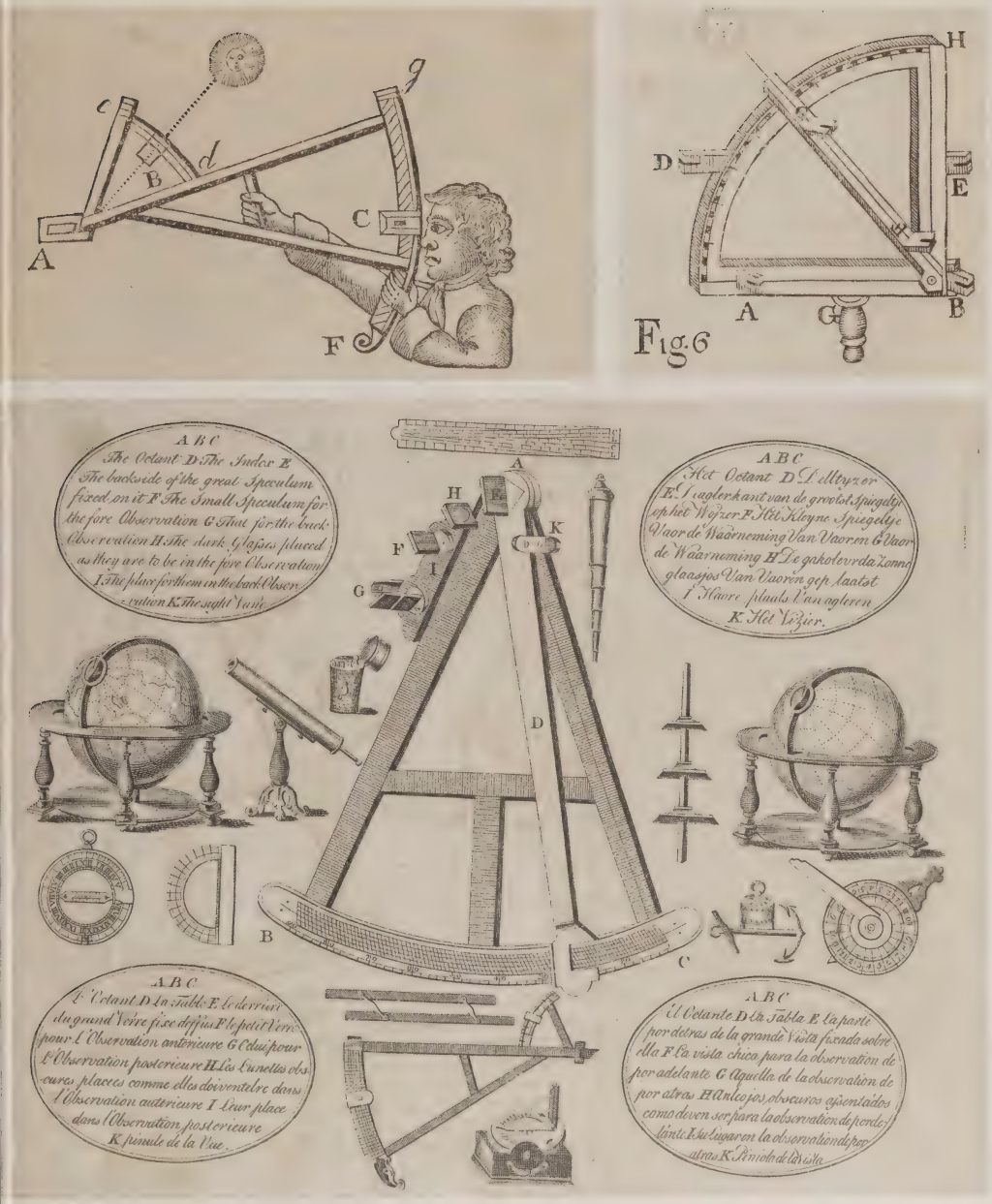
1. Elaborations of this very simple statement of the matter of determining latitude by the North Star, together with diagrams and representations for the instruments employed, are found in Bensaúde, *L'Astronomie nautique*, 136–145, and in Fontoura da Costa, *A Marinharia dos descobrimentos*, 44–60.

and there are references in various literatures which indicate that its earliest use by mariners was occasional rather than continuous, and that its employment on shipboard was to establish direction in storm or fog rather than as an aid in setting and holding a course. In its most primitive form the compass seems to have been a magnetized needle thrust crosswise through a straw and floated upon a bowl of water. It seems to have been just so casual an instrument as this which, Nordenskiöld writes, was described by the poet Guyot de Provins, about the year 1200, as the resource of mariners when the Pole Star was obscured by storm or mist. Other French writers of the early thirteenth century refer to a similar device used at sea, suggesting the probability that it was the Provençal, Catalan, and Basque sailors by whose employment of it the instrument first became known in Europe. But in the writings of an English scholar of the twelfth century, Alexander Neckham, author of the treatises *De utensilibus* and *De naturis rerum*, are passages which indicate to some readers that the mariners known to his experience used an improved form of this instrument in which the needle, as in the land compass of today, revolved about a metal point upon which it was balanced. The Norse of the thirteenth century, too, knew the power of the "leidarsteinn," though a gloss of that century in the *Landnamabok* shows clearly that it had not been a possession of their forefathers who settled Iceland four hundred years before. In 1269, the *Epistola de magnete* of Petrus Peregrinus de Maricourt described a practical compass for use at sea, and as early as 1380, Da Buti, the Dante commentator, gave a description of the mariners' compass in virtually its present form, a revolving card with the north-pointing needle attached to its underside. Even though the apparent whimsies of the needle were sometimes disconcerting to them, the sailors of the Columbian period had an immeasurable advantage over their predecessors of the ancient world in being able, by means of the compass, to keep their direction and maintain their progress far from land in darkness, storm, or fog.

It is probable that the quadrant, the simplest in form of all imple-

ments for the measurement of celestial angles, was also the earliest to be employed for this purpose upon shipboard. It was in use on the vessels of Henry the Navigator, and at that time its employment for observations upon land had long been a commonplace of astronomical practice. It has outlasted all those instruments that have seemed at times about to usurp its place, for in one form or another, with one arc or two, it has been the companion of mariners through the intervening centuries, and today a more learned form of it is found upon every ship in the "sextant" which is really an octant and goes by the name of Hadley's Quadrant, an instrument for the invention of which honors fall equally between Sir Isaac Newton, John Hadley, of London, and Thomas Godfrey, of Philadelphia.

The astrolabe, long known to scholars as a device employed on land in astrological inquiries is spoken of by Raymond Lull in the last decade of the thirteenth century as being then in use by European mariners, though it is probable that at this time its principal function was to find the hour of noon by determining the daily zenith of the sun. There is reason to believe that this instrument had been taken over from the Arabs by the Catalan sailors of the Mediterranean. Whose was the shrewd hand that first stripped the astrological astrolabe of its complexities and rendered it suitable for use upon shipboard is not known, nor is it certain just when this adaptation to a new use occurred. But it is clear enough that for some years before Columbus sailed upon his first voyage the simplified astrolabe had been used at sea by learned observers for the establishment of latitude by the sun and North Star as well as for the determination of the hour. Throughout the centuries of its employment, however, the astrolabe never became an instrument of genuine precision on the swaying deck of a ship, though the Latin races clung to its use long after the English had given it up in favor of other devices intended for the same purpose. One of these instruments preferred by the English was the cross-staff, the *balestilha* of the Portuguese navigators.


A
B
C
F
H
D
E
A
G
B
Fig.6
A B C
The Octant D The Index E
The backside of the great Speculum
fixed on it F The Small Speculum for
the fore Observation G That for the back
Observation H The dark Glasses placed
as they are to be in the fore Observation
I The place for them in the back Observ
ation K The sight Vane
A B C
Het Octant D De Index E
De achterkant van de groote Spiegel
op het Voorste F Het Kleyne Spiegelje
Voor de Waarneming Van Voor en G Voor
de Waarneming H De gekoloverde Zonne
glaasjes Van Voor en geplaatst
I Hoore stuals Van agteren
K Het Vizier.
A B C
L'Octant D La Table E le derriere
du grand Verre fixé dessus F le petit Verre
pour L'Observation anterieure G celui pour
L'Observation posterieure H Les Lunettes obs
cures placées comme elles doivent etre dans
L'Observation anterieure I Leur place
dans L'Observation posterieure
K pinule de la Vue
A B C
El Octante D La Tabla E La parte
por detras de la grande Vista fixada sobre
ella F La vista chica para la observation de
por adelante G Aquella de la observation de
por atras H Anteojos obscuros ajustados
como deven ser para la observation de prend
lante I Sus lugares en la observation de por
atras K Pinnola de la Vista

THREE QUADRANTS: The first (*top left*) is an illustration of the sea quadrant from Colson's *Mariner's New Calendar* (London, 1762); the second (*top right*) is the common quadrant from Pimentel's *Arte de navegar* (Lisbon, 1746); and the third (*bottom*) is from *The Nature and Use of Hadley's Quadrant* (London, 1790). *John Carter Brown Library.*

THE CROSS-STAFF AND THE ASTROLABE. The cross-staff (*top left*) and the astrolabe (*top right*) from Joseph Moxon's *A Tutor to Astronomy and Geography* (London, 1659); and the cross-staff (*bottom*) from Colson's *Mariner's New Calendar* (London, 1762). *John Carter Brown Library.*

It is said that the earliest account of the cross-staff appeared in the fourteenth-century writings of the Catalonian Jew, Levi ben Gerson. In that mention of the instrument it is called, as it was often in later times in various languages, the Baculo de São Tiago, or Staff of Saint James. Adopted, without doubt, because of the physical resemblance of the instrument to the pilgrim's staff, which was one of the emblems of Saint James, patron saint of pilgrims, the name took on a more picturesque significance when this implement of land observation was applied to the use of position finding at sea. Under more learned names it is mentioned by at least two writers of the fifteenth century. The earliest printed description of the instrument seems to be that which appeared, with a pictorial demonstration of its use in measuring both vertical and horizontal angles, in a German blockprint broadside, *Baculus Iacob*, 1502, found in the Library of the University of Bamberg. In his *Margarita philosophica*, edition of 1504, Gregor Reisch describes his quadrant and the Baculus Jacob and pictures both instruments. The incorrect delineation of the transom of the cross-staff in his full-page illustration led him in his edition of 1504 to show a corrected drawing of the implement itself. In his edition of Ptolemy, of Nuremberg, 1514, John Werner described with scientific exactness the construction of the cross-staff, which he called it, and pictured its employment in the measurement of angles. It was particularly adapted to this advancement of Werner's ideas. With it might easily be measured angles in the horizontal or any other plane, a necessity in the method of determining longitude by what came to be known as "lunar distances," first elaborated by Werner in this book of 1514. The astrolabe, on the other hand, could be used only in the vertical plane and was, in consequence, chiefly employed at sea for the purpose of measuring altitudes of sun, moon, and stars. After Werner's learned description of the making and using of the cross-staff, knowledge of it became a commonplace on land among men of scientific employment. It must soon have found its way to sea.

The actual date at which the cross-staff began customarily to be employed as an instrument for the measurement of celestial angles in the art of position finding at sea is a matter upon which only negative conclusions have been reached by historians. Samuel Eliot Morison is emphatic in his statement that the use of the instrument for this purpose was unknown to Columbus at the time of his first voyage. Abel Fontoura da Costa strongly believed that it was not used by Portuguese sailors of the first three decades of the sixteenth century, but then goes on to say that it is mentioned in the manuscript navigation manual of Andrés Pirés of the period 1517–1520. It is a truism that the mention of an instrument or a method in writing suggests its previous employment in practice, but the fact remains that no Portuguese or Spaniard of the Discovery Period is known to have made use of the cross-staff for celestial observation at sea. Its earliest mention in a printed manual of navigation seems to have been in the celebrated *Tratado* brought out by Pedro Nunes in 1537.

The common cross-staff was deceptively simple in appearance and in operation, but it was no less learned in the mathematics of its construction than the astrolabe. This truth is demonstrated by text and by a full-page, beautifully drawn illustration in the section of Lucas Waghenaer's *Mariners Mirrour* devoted to "The Making of a Crosstaf" which briefly describes the finished instrument. But perhaps this illustration, by reason of its very excellence, is not the best for our present purpose. A greatly simplified representation of the principle upon which the instrument was constructed is found in an earlier work the *Breve compendio de la sphera y de la arte de navegar* of Martín Cortés, published in 1551 comprised a light staff of about three quarters of a yard in length crossed at right angles by a shorter, movable staff, or transom. Upon the longer staff was a scale indicating ninety degrees of angular measurement. Sighting along the staff in his noon observation, the navigator moved the transom back and forth until, in a vertical position, one of its ends rested upon the horizon and the other upon the center of the sun.

The figure upon the scale at which the transom stood at the moment of this conjunction gave the angle of the sun's meridional altitude, which, as in the case of the initial reading of the astrolabe in the determination of latitude, must be subtracted from the zenith angle of ninety degrees and further corrected by the addition or subtraction of the angle of declination for the day in question. Previously we have given a more detailed consideration to this procedure, and in our appendix the actual manipulation of astrolabe and cross-staff is described in the words of a sixteenth-century English writer. Columbus had an astrolabe on his first voyage.[2] The precision of this simple device might be rendered less in degree by various circumstances, by a rough sea, for example, or by a clouded or false horizon, by the astigmatism of the observer, or by the effect upon his eyes of the direct rays of the sun.

But no matter what the national preferences may have been as between cross-staff and astrolabe, English and Latins alike were agreed that the astrolabe was, to meet certain conditions, an essential part of a ship's equipment. In its use it was not necessary, except in hazy weather, to gaze directly upon the sun; it was held by its ring upon the thumb and its revolving arm was manipulated until a beam of the sun passed through the slits in the vanes at either end of the arm. There remained but to read the figure upon the scale, found in the outer circle of the instrument. When, as in the lower latitudes, the sun stood well over head at noon it was difficult to use the cross-staff, for the human eye does not readily adapt itself to looking at one and the same time upon zenith and horizon. Furthermore, in the extremely bright, blazing weather of those latitudes, it was with no small difficulty that one fixed his eye upon the sun's center. For these reasons, the astrolabe, a handy instrument, went everywhere with the English seaman even though, for the purpose of his ordinary voyages in the middle latitudes, he

2. See S. E. Morison, *Admiral of the Ocean Sea.* [one volume edition] (Boston, Mass.: Little Brown, 1942), p. 319.

might prefer the cross-staff. Conversely, it was doubtless because so much of their voyaging was in the lower latitudes that the Portuguese and Spanish sailors stood by the astrolabe for general purposes.

The truth seems to be that each of these instruments had its place in the economy of the ship. The frontispiece of this volume (p. 2) shows the vessel in which, presumably, Hans Staden made his Brazilian expedition of 1549. In this drawing are to be observed a mariner measuring a lunar distance with a cross-staff while another, regardless of the time of day, measures with an astrolabe the meridional altitude of the sun. In another celebrated voyage of the century we find Captain Barents making doubly sure, or rather, triply sure of his latitude by taking on one occasion the height of the sun with cross-staff, astrolabe, and quadrant. In the far northern latitude of Nova Zembla where this occurred, the cross-staff could be effectively employed.[3]

It is not to be supposed that either cross-staff or astrolabe was always found in the simple form we have been considering. Thomas Blundeville in his *Exercises* of 1597 tells of several types of cross-staff in use in his day—of Lucas Waghenaer's, for example, which was provided with three movable transoms, and of one of super-excellent qualities constructed by Gemma Frisius, which, unfortunately, was too large for use on board a ship. But when he came to give directions for the use of the cross-staff, Blundeville contented himself with selecting the simplest form of the instrument for the demonstration. Gemma Frisius, in 1545, and John Blagrave, in 1590, were two of several scholars who wrote separately published treatises on the theory, construction, and use of the cross-staff. The astrolabe, too, was improved in theory by various persons;

3. *A True Description of Three Voyages by the North-East towards Cathay and China, undertaken by the Dutch in the Years 1594, 1595, and 1596, by Gerrit de Veer. Published at Amsterdam in the Year 1598, and in 1609. Translated into English by William Phillip.* Publications of the Hakluyt Society, series 1, vol. 13. (London: Hakluyt Society, 1853), p. 24.

Blundeville says that the *Mathematical Jewel* described by Blagrave in his book of that name of the year 1585 was an extraordinarily fine instrument, and he devotes a whole section of his book to its elucidation. The subject of the development of these instruments is one of great complexity. We have Hood's cross-staff and John Davis's back-staff; the simple quadrant, the quadrant with two arcs generally called the Davis Quadrant (the favorite instrument of eighteenth-century American sailors), and, in 1734, Hadley's Quadrant, a device which swept all other instruments of celestial observation from the cabins of ships to the cabinets of museums. It is a subject by itself, and because of its great complexity it may not be gone into further in this narrative of books of the sea.

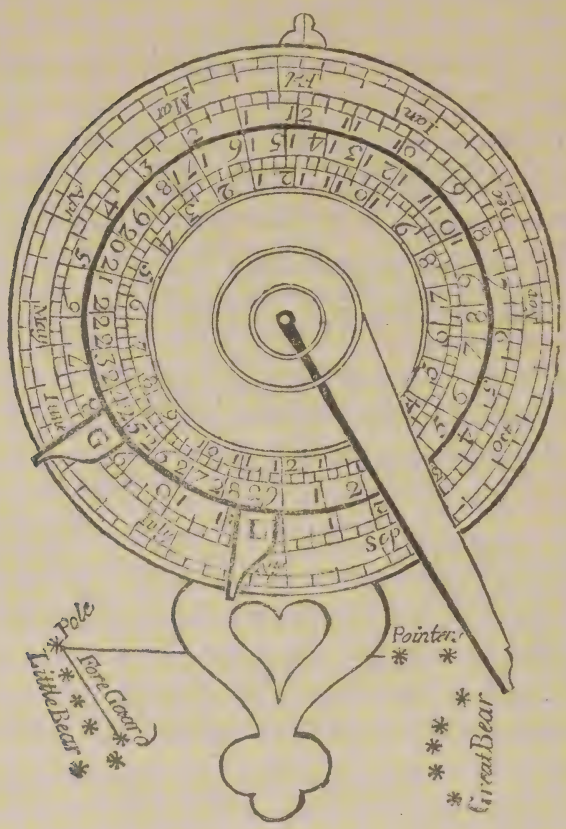
For nearly three centuries after the beginning of the Discovery Period, these three instruments of observation—the quadrant, the astrolabe, and the cross-staff—remained the reliance of such mariners as were capable of finding position by celestial observation. "The Instruments necessarie for a skillful Seaman," wrote John Davis in his *Seamans Secrets*, edition of 1607, "are a Sea Compasse, a Crosse staffe, a Quadrant, an Astrolabe, a Chart, an instrument magneticall, for the finding of the variation of the Compasse, an Horizontal plaine Sphere, a Globe, and a paradoxall Compasse ... but the Sea Compasse, Chart, and Crosse staffe are instruments sufficient for the seaman's use, the Astrolabe and Quadrant being instruments very uncertaine for Sea observations." On his well-remembered voyage to the New England coast in 1605, Weymouth carried with him compass, astrolabe, semisphere, ring instrument, and cross-staff. When Martin Frobisher set out in 1576 for the discovery of the Northwest Passage, he equipped his cabin with the elaborate paraphernalia common to scientific expeditions of all times, but Captain John Smith, writing in his *Sea Grammar* of 1627, declared in his practical way that the "instruments fitting for a sea-man" were "the compass, an astrolabe quadrant, a crosse staffe, a Backe staffe, an astrolabe, and a nocturnall." The compass had been much improved by this time; it was made now, in

Note, That by the Alteration of the Stile, the preſent Nocturnals are render'd erroneous, in ſuch Examples as refer to the Days of the Month; but theſe Errors are eaſily adjuſted, by reckoning and fixing the Index of the Inſtrument eleven Days backwards from the Day of Obſervation; in like Manner as is directed, and done in the Example following.

To find the Hour of the Night, and upon what Point of the Compaſs the Guards are.

To do this, Firſt, ſet the Index of the middle Part to the Day of the Month, then hold the Inſtrument upright, which may be diſcerned by the Tip on the Top of the *Nocturnal*, then look through the Hole in the Mid-

The Figure of the NOCTURNAL.



NATHANIEL COLSON, *The Mariner's New Calendar* (London, printed for W. and J. Mount and T. Page, 1762) illustrates a nocturnal of a type used by eighteenth-century English seamen. Telling time by the stars is an ancient practice, both on land and at sea, but as an instrument for navigational use at sea it was first described by Martín Cortés in his *Breve compendio de la sphera y de la arte de navegar* of 1551. *John Carter Brown Library.*

Smith's words, "for the variation." The back-staff, in the use of which the observer stood with his back to the sun, was a recent and ingenious adaptation by John Davis of the principle of the cross-staff; the nocturnal was intended for the calculation of the hour at night. Though greater in number and more varied in kind, the essential instruments for navigation were still, as they had been for centuries, a compass, a chart, and an instrument for celestial observation.

The Problem of Position

DETERMINING LATITUDE BY THE HEIGHT OF THE POLE

Clearly to be observed in the record of progress in navigation is the fact that the rules of position finding through celestial observation were here in process of formulation and trial throughout the late Middle Ages. It does not follow, however, that the application of those rules at sea was universal or even general in that period. In his *Admiral of the Ocean Sea* Admiral Morison has shown that Columbus, a good practical navigator, was completely inept in the use of the quadrant. He was apparently ignorant, furthermore, of the calculations necessary to determine latitude by the North Star and unable, even, to identify that star with certainty when he wished to measure its height. That procedure, however, had been in use on land long before his time, and in all probability was recognized in his day as a feasible, even though difficult, method by which to determine latitude at sea. Its *regimento reglement*, or rule for that purpose is found fully developed in the earliest printed manual of navigation, the Portuguese *Regimento do estrolabio,* of about 1509, reprinted it is believed, from a lost edition of the late fifteenth century. To what extent this and other rules of the other *Regimento* were in actual use upon shipboard at this time is uncertain, but, slightly later, celestial observation was being employed at sea by certain men learned in mathematics, notably by Antonio Pigafetta, companion of Magellan and survivor of the great voyage.

LATITUDE BY OBSERVATION OF THE SUN

If the sun in its annual circuit of the Earth followed undeviatingly the equinoctial, the celestial great circle concentric with the terrestrial equator, the determination of latitude at sea or upon land could be accomplished by a simple observation and calculation. A mariner north of the equator whose angular measurement of the altitude of the sun at midday was 66° 50′ would merely subtract that figure from 90° and set down the angle of his zenith distance of latitude as 23° 10′ north. But that result, as we know, would be incorrect. As in the case of determining latitude by the North Star, corrections must be made which in many cases give a very different figure.

The sun's ecliptic, that is, its oblique course with reference to the equinoctial, changes in angular value with every instant of time throughout the year and in position north or south of the equinoctial every six months. The figure arrived at by the simple calculation just set down must therefore be corrected by the addition to it or subtraction from it of the angle of the ecliptic figured for midday of the day in question, that is, by the "Declination of the Sun" for that day. The procedure, though simple enough, demands the strict observance of rules concerning the position of the ship north or south of the equator and north or south of the sun itself. These and other considerations combine to form the rule for determining latitude by the sun. A very simple example of the application of the rule would be this:

(a) the measurement of the meridian altitude of the sun, that is, the angle at noon between sun, observer, and horizon.

(b) the subtraction of the meridian altitude from 90°, which gives the complement of the altitude or zenith distance.

(c) if the observer is north of the sun and the sun is north of the equinoctial, the addition of the declination to the zenith distance.

The general formula applying to this particular set of conditions is:

$$Ln = 90° - H + D$$

Reviewing our earlier and incorrect example in the light of this formula we have:

Meridian altitude or H	66° 50′
Zenith distance	23° 10′
Declination north to be added to zenith distance	11° 53′
Latitude north	35° 3′

When all the variations with regard to position of observer north or south of the sun and the position of the sun north or south of the equinoctial have been taken into account, six basic formulas are constructed for the establishment of a ship's position north or south of the equator, that is, its north or south latitude.[4]

In the foregoing sections have been set forth the simplest examples of the procedures through which latitude is obtained by observations of North Star and sun. In ensuing sections we shall discuss the tables of declination employed by the observer and the instruments by means of which he measured his celestial angles.

The Tables of Declination

The angle of the ecliptic, or angle of the sun's course with the equinoctial, is expressed by the phrase "Declination of the Sun." The declination at noon upon the day of observation is, as we have seen, an essential factor in the calculation of latitude. That procedure could not be carried through by the man of average mathematical ability or astronomical knowledge unless he had by him written or printed tables showing in degrees and minutes the declination of the sun calculated for noon at every day of the year.

Tables of Declination seem first to have appeared in European writing in *Le Traité du quadrant* of Robert Anglès de Montpellier calculated for the four-year period 1292–1295. These, the

4. Joaquim Bensaúde, *Histoire de la science nautique portugaise* (Bern, 1912), 122–123.

KL Março tem dias.xxxi.ha lũa.xx.ho. dia.rij.
Lugar.fol
Pisces
d Adrian martyr ⁊ simplici
e Monado martyr ⁊ basilei
f Adarmino martyr pẽça
g Lucio papa ⁊ martyre
A Sam focas martyre.
b Victor ⁊ victorino marti
c Thome ẽ agno confesso
d Appollonio martyre.
e Os q̃reta martyres.
f Alexandre ⁊ gayo martyr
g Quarenta mil martyres
A Sam gregorio papa ⁊ do
b Sam leãdre bispo bispo
c Leeo papa ⁊ martyrr ⁊ do
d longinus martyr.
e Gertruois virgem ⁊ mart
f Patricio bispo ⁊ confesso
g Anselmo bispo ⁊ doutor
A Joseph ẽ nossa senhora
b Gutbberto confessor
c Bento abade fundador
d Paulo bispo ⁊ confessor
e Pigmete preste ⁊ martyr
f Theodoro pbr. Dia ẽ jejũ
g Anũciaçã de nossa senhora
A Sam castorio martyre
b Joam ermitam confessor
c Marcello papa ⁊ gronoan
d Quirino martyr eustasio
e Sam segundo martyre.
f Felice pappa ⁊ babina vi

A TABLE OF DECLINATION. An essential in the calculation of latitude by the Sun. This page is from the *Regimento do estrolabio* of Lisbon, *c.* 1509, the earliest navigation manual, showing the declination of the sun for every day of the month of March. *Bayerische Staatsbibliothek* (from the facsimile published by Carl Kuhn, Munich, 1914, in the series *Histoire de la science nautique portugaise*, vol. 1).

author affirmed, were taken from or based upon the tables of the Arab astronomer, Albategni. Nearly two centuries later, in the period 1473–1478, Abraham Zacuto, a Spanish Jew, constructed his celebrated *Almanach perpetuum*, a work which contained tables of declination adopted by most of the early Portuguese writers on navigation. Though the Zacuto tables seem to have circulated in manuscript form, they did not become current until after their translation from Hebrew into Latin and then publication in printed form at Leiria in 1496. Before this printed publication a rival set of declination tables, those of Regiomontanus, appeared in that scholar's *Tabula directionum*, first printed in 1475. The basic difference between the two sets of tables, and one which makes easy their identification, is found in their respective statements of maximum declination in June and December. Zacuto's figure for the longest day of the year respectively in the northern and southern hemispheres, is 23°33′; Regiomontanus's figure is the more nearly correct 23°30′. On his later voyages, certainly, Columbus seems to have possessed copies of both these sets of declination tables.

The Zacuto tables, cut down to a one-year period, were published in the first printed manual of navigation, the *Regimento* of 1509. A greater service was rendered to navigation in his *Suma de geographia* of Seville, 1519, when Martín Fernández de Enciso presented a set of tables for a four-year period including the bissextile. We shall have more to say later of this feature of Enciso's book.

CHAPTER 3

The Problem of Position Finding and Dead Reckoning

THE SAILOR of the time of Columbus was not able to determine his longitude by time computation, by lunar observations, or by any other procedure known to modern science, but he could, and did, keep a record of the courses and distances run in a day's sailing, and—by conveying to his chart calculation based upon these elements—maintain a surprisingly good record of his position east or west, north or south, with reference to his point of departure. We shall trace later the struggle of the sailors and scholars of several centuries towards a method of determining accurately longitude at sea, observing then that the mariners throughout this long period relied chiefly upon the "dead reckoning" system as their mode of establishing that important factor. That method was made a matter of complicated calculation by the circumstance that the wind is not always directly astern, propelling the ship forward in a straight line. In order to progress against contrary winds, she must sail on various courses or "tacks." To calculate under these conditions the absolute distance east or west covered in a day of sailing upon different courses was an inescapable element in the peculiar and ever-present complexity of life at sea. In discussing the problem of longitude, we shall have more to say about this feature of the mariner's daily and hourly activity.

In his *Sea Grammar* of 1627, John Smith gives a picture which, by the employment of imagination, we can fill with busy figures. "The Stearage roome," he writes,

> is before the great Cabin, where he that steareth the Ship doth alwaies stand, before him is a square box nailed together with woodden

pinnes, called a Bittacle, because iron nailes would attract the Compasse; this is built so close, that the Lamps or Candle only sheweth light to the stearage, and in it alwaies stands the Compasse, which every one knowes is a round box, and in the midst of the bottome a sharpe pin called a Center whereon the Fly doth play, which is a round peece of pace-boord, with a small wyer under it touched with the Loadstone, in the midst of it is a little brasse Cap that doth keepe it leuell vpon the Center. On the vpper part is painted 32. points of the Compasse couered with glasse to keepe it from dust, breaking, or the wind; this Box doth hang in two or three brasse circles, so fixed they glue such way to the moving of the Ship that still the Box will stand steady: there is also a darke Compasse, and a Compasse for the variation, yet they are but as the other, onely the darke Compasse hath the points blacke and white, and the other onely touched for the true North and South. Vpon the Bittacle is also the Trauas, [i.e. Traverse] which is a little round boord full of holes vpon lines like the Compasse, vpon which by the removing of a little sticke they keepe an account, how many glasses (which are but halfe houres) they steare vpon every point. The Whip-staffe, is that peece of wood like a strong staffe the Stearsman or Helmesman hath alwaies in his hand, going thorow the Rowle, and then made fast to the Tiller with a Ring.

Proceeding from south to north on the meridian one must sail 17½ leagues to raise a degree of latitude. No change of course in longitude.

Proceeding on the first rhumb north by northeast one must sail 17⅝ leagues to raise a degree of latitude. The ship in attaining this point is distant from the meridian 3½ leagues.

Carried on from point of departure day by day it was possible to point on the chart both north or south (latitude) and east or west (longitude) position with respect to the point of departure.

Changes in wind would in any distance require tacks or changes of direction. These and the distance run upon each tack would be recorded watch by watch upon a slate of a traverse board and at the end of the day a calculation by right angle triangle made of the

distance made good in both directions and a new point pricked upon the chart. This of course necessitates some method of judging the rate at which the ship was travelling in order to figure the distance travelled upon each tack. This was dead reckoning, the earliest mode of knowing position at sea, used since the 14th century, appearing in a table upon the atlas of Andrea of Biango in 1436, and in use today upon sea ships as a check upon celestial observation, and used virtually exclusively by Columbus.

The table in *Regimento* gives not only the leagues necessary to be run on the several rhumbs to raise a degree of latitude but the distance in leagues east or west of point of departure.[5] Thus position both by latitude and longitude is subjected to a daily check.

In Columbus's day or later it was never wholly a simple matter to keep dead reckoning. A continuous recording must go on day and night, watch by watch, of the distance travelled upon each successive tack, and the distance must be determined by the rate of speed of the ship estimated by log-line or, in the days of Columbus, by some more primitive method than the long chip and knotted line. The navigation manuals of the later centuries are explicit in their instructions for keeping and interpreting those records of rates of speed and courses. Today, despite the existence of numerous mechanical aids, dead reckoning is calculated as scrupulously as ever. The importance of the procedure is nowhere more clearly stated than in Morison's chapter, "How Columbus Navigated, 1492–1504."

With dead reckoning to determine roughly latitude and longitude and with astrolabe and quadrant and declination tables to determine latitude, the sailor of the late Discovery Period, Magellan for example, was proceeding upon principles of position finding not very different from those of today. It is only in the method of determining longitude with accuracy that procedures have undergone basic change in the ensuing centuries.

5. Bensaúde, p. 149

Chapter 3

The Manuals

It was in that undocumented period we call the Dark Ages, curiously enough, that certain changes occurred in the practice of navigation which separated it forever from the rule-of-thumb procedure of the ancients and set it upon the way to becoming a science. We have already seen that in the year 1200 the magnetic compass was recognized as an aid to the mariner in finding his way in the open sea. We turn now to a consideration of the improvement in the mariner's charts and books of sailing directions which took place in that same dim period, when and at whose hands we shall never know.

In considering the form of the sailing directions and the construction of the charts of the Columbian period, we find that there have been definite changes in form though no changes in intention in comparison with those of an earlier day. The *periplus*, or "sailing round" book, of the ancient world has become the *portolano*, or "harbor book," of medieval Europe; the sea chart of Marinus of Tyre has become the manuscript map that we speak of today as the portolan chart.

The existing European and African portolan charts were naturally of no use to Columbus and his successors when they sailed into unknown seas. It was necessary that they form a new cartography, or rather that they enlarge the existing body of cartographical material. There was no break in the method of procuring data or in the method of recording it. The new maps embodying the slowly accumulating knowledge of the New World were in appearance, in mode of projection, and in method of compilation the same as those of the ages gone before. From charts which were often no more than graphic notes, made by ship masters primarily for their own benefit, were soon compiled maps covering larger and larger areas, until within a generation after their discovery the shape of the new continents was known to all literate men. In this way had been accomplished the mapping of the Old World, and from

complete ignorance of the New World in 1492, emerges after 1508 the type of map known as the *Padron Real*, the pattern, or master map, kept for the information of cartographers and mariners in the *Casa de Contratación* at Seville. From this process of recording experience and observation comes also another and more general sort of work, the small-scale portolan atlases made for the general diffusion of knowledge rather than for practical use by mariners—the Cram or the Century Atlas of today as opposed to the practical mariners' charts of the Coast Survey or the Admiralty.

The Portolan Chart

Confusion exists in many minds in the matter of the terminology and definition here expressed. The philology of the word "portolani" is variously interpreted nor will any attempt be made here to arrive at a conclusion with regard to it. In the matter of usage, however, a stand may be taken for the sake of exactness of meaning. Nordenskiöld, to whom all map lovers pay honor, has confused this particular issue by using the word portolan for both written sailing directions and charts. The consequence is inevitable that sometimes in his writing one does not know whether he is talking about a book or a map. I have found no such confusion in books on navigation. When a chart is meant, the fitting word for a cartographical representation is issued in the language of the book. And so it should be.[6]

Small doubt exists that the function of these charts of the thirteenth to sixteenth centuries was to give graphic expression to the written directions in the portolans, and the portolan chart was intended to be used in conjunction with the portolans. Because they were worn out or defaced by usage, there remain relatively few

6. See Konrad Kretschmer, *Die italianischen Portolane des Mittelalters, Ein Beitrage zur Geschichte der Kartographie und Nautik* (Berlin: Veroffentlichungen des Institut fur Meereskunde und des Geographischen Instituts an der Universitat Berlin, 1909).

of the large-scale maps, drawn for short stretches of coast, used by the medieval and Renaissance mariner in the actual navigation of his ship. But happily the professional mapmakers of the period were aware of the value in geographical study of these sectional maps drawn by men to whom correct, instead of casual, recording of experience meant all the difference between death and life, or, at the least, between success and failure in their ventures. Putting together many such charts, the professional mapmaker was enabled to draw the coastal outlines of provinces and countries, and finally—by an infinitely slow process of search, comparison, selection, and rejection—of continents, making small-scale, large-area maps for the diffusion of general geographical knowledge among mariners and students. The pictorial quality of maps drawn in color was early appreciated, and collections of such maps, elaborately decorated and richly bound, were frequently made for the libraries of kings and wealthy amateurs. Except for their smaller scale and greater degree of decoration, the maps composing these atlases were of the same type in style, content, and system of projection as the great pattern maps of the Contratación House and the charts actually employed in the service of the ship. In describing the type, we shall have in mind this finished product, the delicately drawn and brilliantly ornamented atlases of such artist-cartographers of the fifteenth and sixteenth centuries as Andrea Bianco, Vesconte di Maggiolo, and Battista Agnese.

Surely these curious, rare, and lovely portolan atlases are as full of human interest as any species of book that man has put together. In their pages is intelligence in observation and skill in portrayal; in them is patient accumulation of knowledge through years of danger and rough living; and in them, to the imaginative, are romance and the tang of the sea. They present true records of what has been seen and experienced rather than vague poetic guesses as to Hy-Brasil and the lost Atlantis. Within the limitations imposed by an incorrect projection, they represent, carefully, distances and reciprocal relationships in the locations of countries.

It is not merely, therefore, as relics of a bygone era that these Renaissance compilations retain their importance in modern eyes, for in the study of cartography, they fill the gap existing between unorganized knowledge and scientific certainty, between the knowledge of individual mariners, haphazardly recorded or recorded only in memory, and the exact representations of the engraved and printed charts which began to appear in the later years of the sixteenth century.

Most of the examples of the portolan chart remaining today are of the sixteenth century, though there are recorded as existing here and there in great libraries a hundred or more specimens of the fourteenth and fifteenth centuries. The systems of projection accepted by the modern cartographer were unknown to the makers of these charts who, recording more or less correctly distances and directions, represented the earth's surface upon a plane with convenient disregard of its sphericity. In the later examples the modern orientation is employed. Medieval maps with the east at the top, maps of the Roman and Arabic canon with the north at the bottom were forgotten by the practical cartographer of the fourteenth and later centuries. If the shape of his parchment and the proportions of the area to be delineated permitted, he placed the north at the top of the sheet, and in other particulars, such as in the portrayal of a linear scale and the introduction of a compass rose for purposes of orientation, he brought the modern map before us.

The appearance of the portolan chart is generally productive of pleasure to the observer. A network of fine lines radiates in the direction of all the winds from various centers or crossing points known as "wind roses." These lines are drawn in black, green, and red, representing respectively the principal winds, the half winds, and the quarter winds. The crossing points are sometimes decorated with elaborately drawn, vari-colored compass cards. The outlines of the coasts are drawn now in blue, now in green, and again, more splendidly, in gold. Islands are often entirely in gold,

the Red Sea is painted red and nearly always the Islands of Rhodes and Malta are in red quartered by the white cross of the Knights of St. John. Sometimes banners with armorial bearings properly blazoned are used to indicate kingdoms and principalities; place names, finely inscribed, are generally in black, but the use of red for place names of wider importance adds another gracious note of color. Large cities are occasionally represented by clusters of towers, and by bridges and houses drawn in miniature. Intended at first for mariners only, the interiors are blank in the earlier specimens, but in the later charts, the open spaces begin to be filled by these graphic representations of cities, and by correctly located rivers and important ranges of mountains. In the border enclosing the charts, the artist sometimes lets himself go in profuse embellishment; in other cases, a simple design of foliage, real or conventional, satisfies his sense of decoration. Rich and varied coloring, delicacy of drawing, economy of space in the portrayal of intricate matter—these are the physical characteristics that give pleasure to eye and mind in regarding the typical portolan chart. It is in truth, as an old Spanish writer describes it, "a lively picture of the earth and water."

Sailing Directions of the New Era

In our discussions earlier in this book of the sailing directions of the ancient world we left the mariner of that era with an aid to coastal navigation known as the *Stadiasmus,* a work of pilotage put together between the second and fifth century of the Christian era. When in the end of the thirteenth century we find available for the Mediterranean sailor a considerable document in this class, overlooking for this survey certain fragments of the same intention, we learn that as with the maritime chart so with the book of sailing directions, definite advances in effectiveness have come to fruition in the Dark Ages. The book we have in mind as standing close to the beginning of this new era and exemplifying it was the

Italian book known as *Il Compasso da navigaro*, a book of sailing directions compiled about 1254 and known to exist today in a manuscript of 1296. This book and others of its sort which in the Middle Ages and Renaissance we are to call the *portolano*, or in English the portolan, is the direct descendant of the *periplus* of Greek and Phoenician.

In the passing of the centuries the *portolano* as we see it in *Il Compasso* has lost none of the basic features of the *periplus*; it is still in accretional production, formed through the generations by the pooled experience of many individuals; its purpose is still to give the essential information needed by the sailor for coasting voyages in the Mediterranean and Black Seas—making his distances from headland to headland or from harbor to harbor, the dangers to be avoided in the passage, and the comforts to be found in the form of protected harbors and good anchorage. But to the earlier simple statement of distance from place to place has been added, throughout *Il Compasso da navigaro*, compass directions of courses between places in terms of the four winds and the four half winds, that is, *Tramontana* (North), *Levante* (East), *Ostro* (South), *Ponente* (West), *Greco* (Northeast), *Syroco* (Southeast), *Garbino* (Southwest), and *Maestro* (Northwest). Further subdivided these are the thirty-two "points" found upon the compass card of today. This was the first of the significant addition made to the *periplus* of the ancient world by those who put together the *portolanos* of the Middle Ages.

In the next outstanding work to be mentioned the portolan has come to its full development. This was the first printed book of sailing directions, the celebrated *Portolano Rizo*, brought out in Venice in 1490 by the printer Bernardino Rizo, a volume without title, beginning "*Questa e una opera necessaria*." It has been said frequently that this work was the composition of Alvise Cà da Mosto, but it has been shown that, like its predecessors and successors, it too was a work formed by accretion and not the composition of any single author. At the core of it, or certainly interwoven with it,

is the earlier work of which we have been writing, *Il Compasso da navigaro*. The *Portolano Rizo* differs from its predecessor in a distinctive feature, the second of the changes in *portolanos* of which I have just spoken. *Il Compasso da navigaro* was what is known as the "normal *portolano*" concerned with directions for the Mediterranean and the Black Sea. The editor of the printed book of 1499 has burst the bonds of ancient custom and, passing through the Strait of Gibraltar, has embodied in his work sailing directions for the coast of Western Europe and the British Isles. This enlargement of geographical scope is the second of the changes which occurred in the content of the *periplus* as the ancient world gave way to the modern.

The specific source of the directions for the British Isles found in the *Portolano Rizo* is not known, but there is a fragmentary *portolano* that seems clearly to be a relative in some sort of the Italian work, another evidence of the accretionary process through which the *portolano* came to its stature. It is most appropriate that the first printed portolan should have been a book of the new era, giving to the sailor bearings as well as distances and carrying him beyond the Mediterranean to the broad Atlantic, soon to become the fairway of the nations.

A perfect demonstration of the growth by accretion of the book of sailing directions is found in the case of a later edition in French of the *Portolano Rizo*. The compiler of that work of 1490 had promised, but failed to give, a navigation of the northwest coast of Africa in addition to the normal directions for the Mediterranean and Black Sea. When later, in 1577, the book was translated into French and published at Aix-en-Provence in a handsome volume, to say, of extraordinary variety, as *Le Portulan*, it contained in a separate section, in the Catalan dialect, the directions for northeast Africa omitted from the original and, in addition, directions for sailing to Madeira and to and among the Canary Islands. In the usage of the French seaman of the Renaissance and later periods the ancient *periplus* and the Mediterranean *portolano* became

a "*routier*." The English sailor took over this word for his own use but he pronounced and spelled it "rutter." As a Rutter Book, or simply as a "Rutter," any book of sailing directions was known to the English mariner from 1500, or earlier, to the beginning of the nineteenth century.

To go much further into comment upon the later sailing directions would entail for reasons of space a mere listing of titles. Some of them are spoken of in our next section on the "waggoner," the enlarged work in which directions and charts and position finding procedures are found in combination in a single work. We may not leave this subject of the portolan or *routier*, however, without mention of certain works in that sort of a peculiar American interest. The first of these was the extensive section of sailing directions, the first world *periplus*, indeed, which makes up the greater part of a work later to be described in another connection, the *Suma de geographia* of Martín Fernández de Enciso, published at Seville in 1519. Several leaves of this work contain not only the earliest world *periplus* but the earliest sailing directions for the West Indies and the Caribbean coasts in general. These pages contain for America distances, directions, and geographical description based upon the personal experience of Enciso and his associates. For the old world of Europe, Asia, and Africa the work of the ancient geographers has been amended and extended by this information obtained from Portuguese and other explorations of the age of discovery. Enciso's book of directions enlarged the horizons of mankind.

To the North American the most interesting of the *portolanos* or rutters that came into print between the *Portolano Rizo* of 1490 and their own *American Coast Pilot* by Lawrence Furlong of 1796 are two notable French productions of the sixteenth century. *Les Voyages avantureux* of Jean Alfonce was first published at Poitiers in 1559. *Les Voyages avantureux* of Martin de Hoyarsabal, a publication of 1579, appropriated the title of the earlier work to advertise a different and superior publication.

THE

AMERICAN COAST PILOT;

CONTAINING,

The Courſes and Diſtance from *Boſton* to all the principal Harbours, Capes and Headlands included between *Paſſamaquady* and the Capes of *Virginia*——WITH

DIRECTIONS

For Sailing into, and out of, all the principal Ports and Harbours, with the Sounding on the Coaſt——ALSO,

A TIDE TABLE,

Shewing the time of High Water at Full and Change of the Moon, in all the above places——TOGETHER

With the Courſes and Diſtance from *Cape-Cod* and *Cape-Ann*, to the ſhoal of *Georges*, and from ſaid *Capes* out in the South and Eaſt Channel, and the ſetting of the current to the Eaſtward and Weſtward———

——ALSO——

The Latitude and Longitude of the principal Harbours, Capes and Headlands, *&c. &c. &c.*

BY CAPT. LAWRENCE FURLONG.

ALSO—Courſes, Directions, Diſtances, *&c. &c.* from the *Capes* of *Virginia*, to the *River Miſſiſippi*, from the lateſt Surveys and Obſervations.

(Approved by experienced Pilots and Coaſters.)

THE FIRST EDITION.

PRINTED AT NEWBURYPORT, BY

BLUNT AND MARCH,

Sold by them and the principal Bookſellers in the *United States*——1796.

Furlong's *American Coast Pilot.* A relatively late descendant of the *Periplus of Scylax. John Carter Brown Library.*

The Alfonce book, written by a pilot of the Roberval expedition, contained a few directions for the Breton and Basque fishermen who even then were making audacious voyages to the Newfoundland banks. Though printed in 1559, it seems actually to have been earlier in point of composition than the greatly more extensive directions in the same author's *Cosmographie* of 1545, but that work remained in manuscript until the nineteenth century and so may be presumed to have exerted little influence upon its contemporaries. When the Hoyarsabal *routier* appeared, the French had become more fully aware of the value of the Newfoundland fisheries; they were sending an expedition just then under the Marquis de la Roche to explore and colonize Canada, and it may be indicative of intelligent purpose that the Hoyarsabal contained some twenty pages of directions for the Newfoundland and Labrador coasts. At any rate, this *routier* went through many editions and was carried in the cabins of the French fishermen and sailors for a century. It was superior to anything of the sort possessed by the English sailors of the day for that area, and who can say how great was its influence upon the course of empire?

The Waggoner, a New Aid to Pilotage

If the destiny of nations, as just suggested, was affected by the advantage the French drew from their possession of the *routiers* of Jean Alfonce and Martin de Hoyarsabal, there is an instance now to be spoken of in which the influence of a single book of the sea upon world history seems even more direct. In 1584, Lucas Janszoon Waghenaer, a Dutch pilot, brought out at Leyden the first part of his *Spieghel der zeevaerdt*, a work of a new sort in that it brought together for the first time in a printed volume a treatise on the science of navigation, including a description of its instruments; a collection of detailed sailing directions; and a set of charts. This work was not only the earliest printed sea atlas, but because of the presence in it of sailing directions based upon its

charts, it established a genre that remained the familiar possession of sailormen until, in later centuries, charts became so detailed and were drawn on such a large scale that they could no longer be conveniently contained within the covers of a book. The Waghenaer book was concerned only with the coasts of western Europe; it was particularly detailed in its maps and directions for the Narrow Seas, those difficult waters that washed the coasts of England, France, and the Low Countries. In 1585 appeared the second part of the book, dealing with the northern coasts of England, the coasts of Scotland, Norway, and the northern countries in general. Close to so many interests—the interests of seaman, merchant, and man of war—the reception of the *Spieghel der zeevaerdt* in England was such as to warm the heart of its author, who had published the elaborate volume at his own expense. The Lord High Admiral, Charles Howard of Effingham, immediately presented it with commendation at the royal council table, where a translation of the work into English was determined upon. Out of this action came *The Mariners Mirrour*, an official translation of Waghenaer's book by Anthony Ashley, published sometime after October 20th in 1588. A few months before this translation appeared, Lord High Admiral Howard, with Sir Francis Drake and a sturdy fleet, set out from Plymouth one day to meet the great Armada with which Philip of Spain proposed to change the political map of his world. The victory in the running fight of two weeks' duration which then ensued must have been in some part affected by the knowledge of the Narrow Seas the English possessed. Nowhere at that time were the winds, currents, shoals, and harbors of those coasts so clearly set down as in the Dutch charts and sailing directions which Howard had commended to the Council. The Spaniards, too, had Waghenaer's book, but their strategy in the battle does not indicate that they made great use of it, while the strategy of Howard seems to have been based upon intimate knowledge of the waters in which it was fought. One would like to believe that here was an instance in which great events were

determined by a book of the sea. The English translator, writing a short three months after the battle, seemed to recognize some connection between the recent national triumph and his book, for on its title-page he proclaimed that from it might be understood "the exploits lately atchived by the right Honorable the L. Admiral of England with her Maties Navie and some former services don by that worthy Knight Sr. Fra. Drake." The reference to Drake was doubtless intended to call to mind that time in 1587 when Sir Francis had sailed to Cadiz and there had accomplished the "singeing of the King of Spain's beard" by destroying so much of his fleet as to force the postponement of its attack upon England for another year, thus giving the English time for the organization of their defense. Certainly, Waghenaer's chart and his directions for entering Cadiz Harbor were explicit enough to have given Drake conspicuous aid on that occasion.

The *Mariners Mirrour* was one of the handsomest books of its time. Its title-page and many of its maps were engraved by Theodore de Bry, then at work in England, who, two years later, was to begin the publication in Frankfurt of that great series of reprints of voyages which, in noble typographical dress and with splendidly engraved illustrations, was to prove a delight to bookmen from then until now. Others of the maps were by Jodocus Hondius, a Dutch engraver and cartographer, well remembered to this day, who was also at that time employed in England. It contained, among other things, explicit directions and a full-page plan for the correct construction of a cross-staff. Its sailing directions were directly keyed to the charts which accompanied them. These charts were drawn upon the old equidistant projection of the portolan charts, for the Mercator chart was not yet understood by practical sailormen. But as the charts were drawn for relatively small areas, they were sufficiently correct for their purposes. From a recent discussion of this great book, one learns that of Part I alone and of Parts I and II together, there were issued by 1620 a total of twenty-

four editions and issues in the Dutch, French, German, Latin, and English languages.[7]

Works of the sort represented by the Waghenaer book became part of the equipment of every well-found ship, and any collection comprising sailing directions and charts was spoken of among English sailors as a "waggoner" long after the original sense of the word as the name of the author of the *Mariners Mirrour* had been forgotten. Thus it was as "waggoners" that the English sailors thought of the *Fierie Sea-Columne*, translated from the Dutch in 1633; of their *English Pilot*, of 1689, and many successive editions; and of their *Oriental Pilot*, or *East-India Directory*. Another book in this class of a more elaborate character than these, a book modelled, indeed, in most details, upon the *Mariners Mirrour*, was *Le Grand & nouveau miroir ou Flambeau de la mer*, translated into French from the Dutch in 1672. The *English Pilot*, of which the Fourth Part dealt with the "West India Navigation from Hudson's Bay to the River Amazones," was a favorite of American sailors from its first appearance in 1689 almost throughout the eighteenth century, though perhaps late in the century it found a rival in Jefferys's *North American Pilot* of 1775, a work which two years later appeared also in French. The time had come when national secrets were not so carefully guarded as in the days when governments fondly believed that by edict and ordinance knowledge of the shape of their lands and waters could be kept from other nations. Even so, it must have been, or would have been if they had known of it, something of a shock to the French, when, in 1759, an anonymous British author declared to William Pitt that the conquest of Quebec had been immensely simplified by the chart of the St. Lawrence which Father Charlevoix in 1744 had published in his *Histoire et description generale de la Nouvelle France*. But the greatest

7. See, for example, C. Koeman, *The History of Lucas Janszoon Waghenaer and his "Spieghel der zeevaerdt,"* (Lausanne: Sequoia S.A., 1964), pp. 63–65.

of all the "waggoners" was that which J.F.W. des Barres compiled in 1780 at the order of the Admiralty for the use of His Majesty's ships in American waters. *The Atlantic Neptune* is the "waggoner" in full dress, the old Pilot wearing white tie and tails, so to speak. These huge folio volumes contain some 257 North American charts and colored engravings of American ports as seen from the sea. It is one of the great books in many senses, and its compiler spent twelve years or more trying to recover from Parliament the £8,800 he claimed to have spent of his own money in connection with a project that cost the Admiralty, all told, something like £100,000.

This book may indeed have had something to do with the change in custom that soon came about. The great size of its charts made the volumes containing them difficult to handle. Soon we find governments issuing the large charts individually and on separate sheets for convenience in use. Sailing directions to be used with a group of such charts were given once more an entity of their own as a separate genre, separately bound. That is the custom today, as it was in the fifteenth century; the "waggoner" was a noble experiment that failed to fulfill all the requirements of the case. The last use of the name in American writing was probably by Bernard Romans in his *Concise Natural History of East and West Florida*, published in New York in 1775.

CHAPTER 4

The Components of the Manuals

WE PASS now from consideration of the instruments and other aids of the navigator at the close of the medieval period to speak briefly of those manuals of the ensuing centuries in the pages of which the rude customs of the sea found restatement as the science of navigation, and wherein the rules of thumb of various races in many periods became the exact formulae employed by all men in our own time.

There existed in the Columbian and pre-Columbian periods no separate treatise upon the subject of navigation as a practical science. The voyages of Columbus were over and done and a new era in exploration begun before a true navigation manual came into being, but Columbus and the men of his time possessed a more respectable fund of general and special knowledge than we are normally inclined to credit them with. They had, to begin with, a large geographical literature at their disposal; the treatises of Strabo, of Pomponius Mela, and of Claudius Ptolemy, issued in print with commentaries by Renaissance scholars, helped men of that time to the formulation of ideas upon the shape of the earth and the reciprocal positions of its known lands and seas. The current commentaries upon these revived Greek and Latin texts proved of direct usefulness in the development of navigation science. It was, for example, in the Ptolemy of 1514 that the editor, John Werner, gave the earliest elaborate description of the cross-staff and explained the learned system of finding longitude at sea by the "lunar distance" method, later to be described, which was practiced to some extent until the twentieth century. It was in a Ptolemy, also, Pirckheimer's edition of 1525, that the common plane chart was

first subjected to criticism and the way pointed to the rectification of its errors.

In addition to these books of a general character, the pilot of the time of Columbus had available in printed or manuscript form certain separate treatises which in due time were brought together to form the *Regimento do estrolabio*, the notable little book which, about the year 1509, began the long series of practical treatises we know as the manuals of navigation. Understanding of the manuals is based upon acquaintance with the separate treatises which composed them, upon that and upon the motive which underlay their making. Before we examine those works which were the essential components of the book of 1509, we must remind ourselves that the great efforts of the sixteenth century in the formulation of the science came about through the need of a code of practice that would enable ships to go safely to and from America and India, and to explore the enormous coasts which had been brought to knowledge through the enterprise of Columbus and Vasco da Gama. There had been relatively little need of such a science in that long unchanging period of classical times and the Dark Ages, when most voyages were carried out in the Mediterranean or along the familiar western coasts of Europe. But one must not forget, however, that voyages to the Azores were not mere coastal voyages.

Sacrobosco & the 'Sphaera Mundi'

The first requisite of the pilot in the broad ocean was an understanding of the basic principles of astronomy. All that was known of the celestial world in the Middle Ages was stored in the *Almagestum*, "the greatest" book, of Claudius Ptolemy. First-hand knowledge of the *Almagest* could not be expected of any save scholars, but when need for a more general acquaintance with its matter, it was supplied in the immemorial manner. The handy digest of the great book that was made in the thirteenth century, the *Sphaera mundi* of

Johannes de Sacrobosco, became one of the best known and most useful books of all time. Its author, John Holywood, of Halifax, was an English-born scholar who lived out his years at the University of Paris, and sometime before his death in 1256 abridged and translated into Latin the basic theories and principles set down at length in the *Almagest*. There is no record of the extent to which the book was used in manuscript before the invention of printing, but its value to students became generally apparent from the moment of its first publication in type at Ferrara in 1472. One counts without great difficulty twenty-six separate editions of the little paraphrase from fifteenth-century presses. Separate editions of it continued to occur in various languages throughout the sixteenth century; in one case it was published with a commentary which, ironically, makes a work almost as extensive as the *Almagest*, the large book from which it had originally been abstracted. But these separate editions of the book in the sixteenth century hardly interest us; it is the presence of the treatise as a fundamentally important element in the navigation manuals of that century which attracts our attention again and again. It forms the larger half of the first of the manuals, and, in one version or another, expanded, contracted, or paraphrased, it is recognized as an essential feature of all the manuals of the century. Rarely has any book served so great a usefulness in the world as the little treatise which the English scholar prepared, let us make an imaginary flight, as a syllabus to the *Almagest* for his students in mathematics at the University of Paris. All men of inquiring minds of that day sought to learn the relationship between the earth upon which they stood and the heavenly bodies above them, and here in Sacrobosco's little book was that knowledge boiled down and sugar-coated for easy absorption. Particularly must mariners have this knowledge, and on this account we find that Sacrobosco's treatise on the sphere, in one form or another, is invariably a component of the early navigation manual.

Abraham Zacuto & the 'Almanach perpetuum'

Another essential feature of that *Regimento* which began the literature of navigation science was a set of tables recording the sun's declination, that is, its angular distance north or south of the celestial equator for every day of the year, an item of information essential to the determination of latitude. There is no doubt that such tables in a primitive degree of development were among the early possessions of astronomical science. It has already been said that tables for a four-year period, including a leap year, were compiled at the close of the thirteenth century by Robert Anglès de Montpellier. It may have been upon the basis of these that a set of such tables, destined to great usefulness, was brought out just two hundred years later by Abraham Zacuto, a Spanish Jew, born about 1450, who taught astronomy at Salamanca and Saragossa, and who fled to Portugal when his race was proscribed in Spain. There, the parallel is familiar today, he was befriended by the King and made court astronomer and historiographer. He must have been a relatively young man when he compiled, in Hebrew, between 1473 and 1478, his *Almanach perpetuum*. Translated into Latin, printed at Leiria in 1496, this book became an element of great importance in the history of navigation.

Just as there exists a group of border-line figures in the history of chemistry, men whom one hardly knows how to classify, whether as chemists or as alchemists, so in the history of the science of the celestial universe, the astronomer is constantly being confused with the astrologer. That condition is one of the anomalies which make delightful the story of the past. Undoubtedly, it was as an astrologer that Zacuto was first consulted by King Manuel on the probability of success attending his project of establishing a sea route to India by way of the Cape of Good Hope. And it was as an astrologer that Zacuto delivered the King a prediction of complete success. Furthermore, Zacuto's *Almanach perpetuum* was compiled originally for no other purpose than that of astrological prognosti-

cation. It is an interesting reflection that it served equally well the needs of exact science. When the expedition to India was being planned, Zacuto was regularly consulted as to technical and scientific matters, and it seems that the Tables of Declination he gave Vasco da Gama was a considerable element of success in the ensuing passage to India. Especially was this true, the story goes on, because Zacuto constructed for the leader an astrolabe of metal and taught the pilots its use in connection with his tables. Out of the strange mingling of the true and the fanciful in this story emerges the fact that Zacuto's Tables of Declination came into their own in the grand manner through their employment on one of the greatest of voyages. All the rest may be embroidery upon that fact.

It must not be supposed that only in the work of Zacuto are to be found Tables of Declination at this time. Zacuto's tables were hardly compiled, certainly not printed, when in 1475, the *Tabula directionum* of Regiomontanus, that is, Johannes Müller of Königsberg, appeared in print. The reason for emphasizing the importance of Zacuto's compilation, rather than the equally valuable work of Regiomontanus in the same field, is that the earlier Portuguese and Spanish books which so greatly affected the history of navigation science, most books of the sort, indeed, until Pedro Nunes wrote in 1537, invariably employed the tables of the learned Jewish astronomer. The small fact that the tables of the German were correct and Zacuto's some three minutes out of the way in their statement of the maximum declination, has no bearing upon the circumstance that the most notable nations at sea of the early sixteenth century used the Zacuto tables, and that it was these nations which introduced into navigation practice the determination of latitude by the height of the sun.

The Earliest Manual, the Portuguese 'Regimento'

The literature of navigation as a separate science could not begin until its several elements had been forged into one body. This uni-

fication of knowledge occurred in intention, if not in all completeness, when an unknown Portuguese combined in a single manual the three books (or, one book and parts of two others) that we have been speaking of, that is, Sacrobosco's *Sphaera mundi* in a Portuguese translation, the rules for position finding, and a table showing the angles of declination of the sun for one year, based upon the more elaborate tables in Zacuto's *Almanach perpetuum*. Accompanying these three sections were directions for the use of the tables in finding the latitude by observation of the sun; a list of latitudes of places determined by the height of the North Star; directions for determining latitude by the North Star; and a traverse table for the determination of the dead reckoning of the course, that is, for the rough determination of longitude and latitude. This book was the *Regimento do estrolabio y do quadrante,* the foundation manual of practical navigation towards which the several preceding paragraphs have been pointing. It is known in at least two separate editions before 1520, of which the earlier, printed in Lisbon, seems to be that represented by a single copy, with date of publication torn off, in the State Library at Munich. It is not possible to say when the book was first composed or when it was first printed, but Joaquim Bensaúde, Portuguese historian of nautical science, suggests that the Munich volume is a second edition, printed sometime between the years 1509 and 1518. All later treatises on navigation, down to those of our own times, may be thought of simply as revised, enlarged, and emended editions of this work on the fundamental principles of astronomy and position finding. The elaborate treatises of today have evolved step by step from this earliest statement of their principles. Between the appearance of the *Regimento* in 1509 and the publication in Newburyport, Massachusetts, in 1802, of Nathaniel Bowditch's *New American Practical Navigator*—in its later editions the *vade mecum* of the American sailor of today—stretches a period prolific in works of a similar intention and of constantly increasing fullness in form and exactitude in statement. It is by reference to some of these treatises that we are

able to trace progress in the science of navigation throughout the three centuries in which occurred its greatest development.

The First Spanish Manual

In 1519, Martín Fernández de Enciso, a Spanish mariner, political official, and cosmographer, brought out in Seville his *Suma de geographia*, a work which for a long time was regarded by historians as standing in point of priority at the head of the list of treatises on navigation. In its section relating to that science it contains little that is not found in the Munich copy of the *Regimento do estrolabio*, and Joaquim Bensaúde, vigorously assertive in this matter of the priority of the Portuguese, affirms that the navigation section of the *Suma de geographia* is merely a copy of the *Regimento* and a poor copy at that. But despite that adverse criticism, one can only regard the book of Fernández de Enciso as a distinguished work containing the tables and rules of position finding; Sacrobosco's treatise on the sphere; and a section in which all the countries of the world are described as to reciprocal situation, latitude, and political condition for the benefit of the mariner and the general student. It was republished in emended editions in 1530 and 1546, and a translation by John Frampton of the American portion of its geographical section appeared in English in 1578 with the title *A Briefe Description of the Portes ... of the Weast India*. A translation of virtually the whole work into English, with changes and modifications, was made by Roger Barlow about the year 1541, but that potentially valuable work unfortunately remained in manuscript until long after its practical usefulness was at an end. In 1932, it was brought out by the Hakluyt Society as a document illustrative of the knowledge and practice of the past.[8] If Henry VIII had listened to the translator's plea and provided for the publication of

8. Roger Barlow, *A Brief Summe of Geographie*. Edited with an Introduction and Notes by E. G. R. Taylor, Publications of the Hakluyt Society, series II, vol. 69. (London: Hakluyt Society, 1932).

his book, we might have had England a factor upon the high seas and in America two generations before she turned in earnest to the world beyond her own shores.

Faleiro & a Century of Error

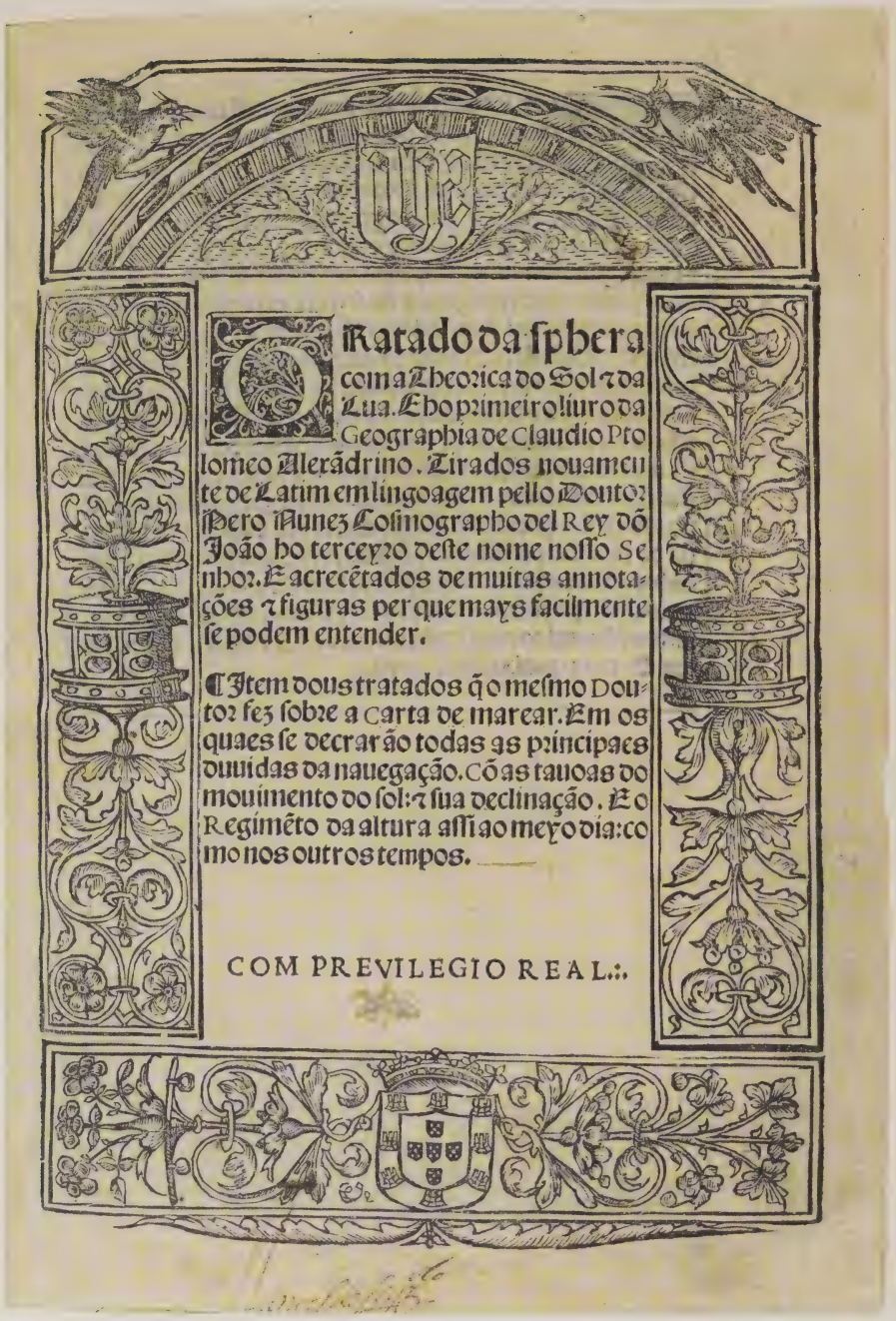
Fernández de Enciso's book was followed by the publication at Seville, in 1535, of Francisco Faleiro's *Tratado del esphera y del arte del marear*. A Portuguese and a former associate of Magellan, Faleiro had been for some years resident at the Court of Spain when the Queen, in 1532, gave license for the publication of his study in navigation. Again, in this manual, we find the persistence of the model established by the *Regimento*. Faleiro begins his book with his own version, in Spanish, of Sacrobosco's work on the sphere, and follows it by a section in which he has enlarged, corrected, and brought up to date the practical portions of the *Regimento*. It is unfortunate that his original personal contribution, the section on longitude, should have proven to be utterly without value in practice. His proposed method of determining longitude by the variation of the compass, based upon the calculations of his brother, Ruy Faleiro, turned out to be one of those examples of false dawn in the history of science which serve only to keep the minds of men fixed upon wrong considerations. As a practical manual, however, this Spanish work by a Portuguese writer surpassed in every particular anything that had preceded it. Faleiro's little volume has unusual merit in the eyes of collectors, for to its intrinsic importance is added the grace of exceptional rarity. There are copies in Munich and Augsburg and a third in Providence, the possession of the John Carter Brown Library.

Pedro Nunes & the Greatest of the Manuals

The work of Faleiro anticipated in publication by only two years the greatest of the early books on navigation, the celebrated *Tratado*

¶ Tratado del Esphera y del ar
te del marear: conel regimiẽto de
las alturas: cõ algũas reglas nue
uamẽte escritas muy necessarias.
Con priuilegio Imperial.
M.D.xxxv.

TITLE-PAGE of the *Tratado del esphera*, of Francisco Faleiro, Seville, 1535, a manual by a Portuguese published in Spanish. *John Carter Brown Library.*


TRatado da ſphera
com a Theorica do Sol & da
Lua. Ẽ do primeiro liuro da
Geographia de Claudio Pto
lomeo Alexãdrino. Tirados nouamẽ
te de Latim em lingoagem pello Doutor
Pero Nunez Coſmographo del Rey dõ
João ho terceyro deſte nome noſſo Se
nhor. Ẽ acrecẽtados de muitas annota-
ções & figuras per que mays facilmente
ſe podem entender.
¶ Item dous tratados q̃ o meſmo Dou-
tor fez ſobre a Carta de marear. Ẽ os
quaes ſe decrarão todas as principaes
duuidas da nauegação. Cõ as tauoas do
mouimento do ſol & ſua declinação. Ẽ o
Regimẽto da altura aſſi ao meyo dia: co
mo nos outros tempos.
COM PREVILEGIO REAL.

TITLE-PAGE of the *Tratado da sphera*, by Pedro Nunes, Lisbon, 1537, the most comprehensive of the early works. *John Carter Brown Library.*

da sphera, composed by Pedro Nunes, a Portuguese mathematician, and published in Lisbon in 1537. The first part of this book contains Portuguese translations of Sacrobosco's treatise on the sphere, of Purbach's treatise on the sun and moon, and of the first book of Ptolemy's *Geographia*. The second part discusses various problems in navigation, and the third, under the head "Tratado em defensam de carta de marear," enters upon an elaborate examination of the nautical chart. To the interpretation of existing knowledge, Nunes brought a more critical form of intelligence than had been possessed by his predecessors.

In his section on practical navigation he goes more fully than any before him had done into the accepted theories and methods, ignoring, however, the method of determining longitude by the variation of the compass, as a practice based upon insufficient data. He describes for the first time the loxodromic curve. He calls attention to the errors in the plane chart in common use, and in attempting their rectification, shows himself the connecting link between Pirckheimer, who had discussed this matter in 1525, and Mercator, whose great planisphere of 1569 gave the most generally satisfactory solution to the problem of map projection. He described also the mode we know today as "great circle" sailing; that is, the mode of sailing by which the pilot plots his course along the arc of the earth's surface formed by a plane passing through the center of the earth and two given points on its surface, in brief, the shortest surface distance between the points. The "great circle" mode had been in men's minds for many years: Sebastian Cabot, it is said, had proposed such a course across the Atlantic in 1498; Verrazano had actually employed the method in his American voyage of 1524; but it is in the Nunes book that this commonplace of modern navigation was first set forth in a printed treatise as a principle of the new science. Writers on navigation science come back time and again to the Nunes book of 1537 as to a sure point of departure. Though it is but a development of the foundation work, the *Regimento do*

estrolabio, containing the elements which went to form that book, it is a new thing in many ways—chiefly in that it is the product of a critical scholar, who accepted nothing without testing its truth. Thus Nunes had nothing to say about Faleiro's method of finding longitude by the variation of the compass; he discarded the Zacuto tables, hitherto held to by the Portuguese writers, with their maximum declination placed at 23° 33′ and adopted the results of Regiomontanus in which the maximum is correctly given as 23° 30′. These things gave confidence to the men of his time, and they have led scholars since then to point to his book as the work in which navigation practice came first into the realm of exact science.

Medina & Cortés, Spanish Followers of Nunes

In 1545, at Valladolid, the Spaniard, Pedro de Medina, brought out his *Arte de navegar*, an immensely popular book republished during the next century in thirteen editions in Spanish, French, Italian, and English. A Spanish writer quoted by Martin Fernández de Navarrete in his *Biblioteca maritima española* says that navigation was studied in France from the *Arte de navegar* of Pedro de Medina; in England from the *Breve compendio* of Martín Cortés. Sure enough, we find that to English and American readers it is the work of Medina's successor, Martín Cortés, which is especially interesting.

In 1551 appeared in Seville the *Breve compendio de la sphera y de la arte de navegar* of the Spaniard, Martín Cortés, the most comprehensive nautical work of the later period. Richard Eden, that notable promoter of the study of the sea among the English, translated this book ten years later, and in this form it was the handbook of the English mariner for a generation. Cortés embodied in his book the most complete statement of the science of navigation that had yet appeared, and he not only understood the faults of the plane chart, but forecast clearly the principle its improvement was to be

based upon eighteen years later in the construction of the Mercator projection. His practical descriptions of the construction of cross-staff and astrolabe were adequate and well illustrated. On the purely scientific side the book is rendered notable by the fact that in its pages the Spanish writer made for the first time in print the suggestion that the magnetic pole and the true pole of the earth were not the same. The publication of this work completed the tale of navigation progress among the Spanish and Portuguese that began with Henry the Navigator at Sagres. Thenceforth progress in the science was to be the contribution of men of other nations.

The Earliest American Contribution

As so great a part of the advance in the science of navigation was brought about in this period by the necessity for safe and comfortable passage to the New World, and for intelligent exploration of its enormous coastal area, it is gratifying to find that one country of America in a relatively early period of its existence repaid that interest by the production of a work of navigation. In 1587, twenty years before the English settlement at Jamestown, the *Instrucion nauthica* of Diego García de Palacio was published in Mexico City. Its author had previously written and published in the same place a work on military science, and as he was a writer of general rather than of special attainments, we are not surprised to find that his book on nautical matters, presented in the form of a dialogue, seems to be purely a restatement of current lore of the sea. It is an original production, however, in that it is written with the latitude of Mexico City in mind, in its inclusion of a section on shipbuilding, and further, in that it contains at the end a vocabulary of current sea terms. In the literature of navigation and of shipbuilding in America, this excellent compendium holds an uncontested position of priority.

The Expanding Science

Not the least remarkable feature of the Renaissance was the physical manifestation of the movement, the explorations by which silent continents were discovered to the eye of man in the same measure that unknown worlds of the spirit were opened to his inner vision. As a study in a Renaissance bypath, therefore, the navigation literature of the time has peculiar interest. The best of the mathematicians and astronomers of the period applied their knowledge to the science of navigation. What a terrible complacency we of the twentieth century are prone to display in this matter of physical science! We are, or should be, humbled when we look at the works of Gemma Frisius, the Flemish mathematician, and of Peter Apian the German, look at the results of their inventiveness, their "astronomical rings," "horoscopions," and other curious and wonderful contrivances. The very refinement and ingenuity of their inventions in many cases prevented them from taking the place at sea of the simple cross-staff and the astrolabe. Blagrave's *Mathematical Jewel*, an English work, described a technically correct, but very complicated universal astrolabe that never came into general use despite the contemporary commendation it met with, especially from Thomas Blundeville who, in 1597, devoted a separate section of his *Exercises* to a consideration of it. Before the simpler principle of Hadley's Quadrant could be evolved it was necessary for the human mind to try and reject many mechanisms of learned complexity. We must pause here another moment to reflect that the principles of astronomy and navigation were formulated under conditions of empiricism that seem incredible in view of the results attained in their practical application. Francisco Faleiro and Pedro Nunes wrote several years before the *De revolutionibus orbium* of Copernicus was published in 1543, and though Martín Cortés issued his useful work on navigation science nine years after this notable event, he yet included a chapter in which,

to his own satisfaction, certainly, he labored the proposition that the earth does not move.

A Duke & the Secrets of the Sea

It has been easy enough so far in this narrative to classify the books discussed. We have had books of sailing directions, books of charts, and the combination book in which, as in the *Mariners Mirrour*, sailing directions and charts were brought together in one volume. Then as an entirely separate group we have had the practical navigation manuals. All that was clear and simple, but now comes a difficulty. What is one to do with a book that is a combination of all these; to be specific, with that most ambitious work in the literature of the sea, the *Dell'arcano del mare* of Sir Robert Dudley? This mighty work attempts to set forth in its pages all the secrets of the sea; it is a book of sailing directions, a treatise on shipbuilding, on the making of nautical instruments, on the principles of practical navigation, on the finding of longitude, and on naval warfare; it is also, preeminently, perhaps, an atlas in which many of its 130 or more large-scale charts are drawn, for the first time in a printed atlas, on the Mercator Projection. At about the age of 30, after a notable career on sea and land in the fashion of the Elizabethan gentleman adventurer, Dudley forswore his country and his wife, and went to live in Florence at the court of the Duke. The writ of the Star Chamber, denying his right to the titles of his father, Elizabeth's Earl of Leicester, did not run in Italy, and his legitimacy was not questioned by his continental associates. He there assumed not only the titles of Earl of Leicester and Earl of Warwick, but through his princely patrons he was able to have confirmed by the Emperor his claim to the still higher title of his grandfather, the attainted John Dudley. It was, therefore, chiefly as Duke of Northumberland that he was known thenceforth in Italy, where he lived actively as engineer, naval architect,

and courtier. But in England neither his achievements nor his titles were regarded as sound, nor did he ever return there to push his claims after his flight in 1605. Grandson to two lord high admirals of England, John Dudley and William Howard, nephew to another, Charles Howard, drawn to the sea, furthermore, by natural inclination, he devoted himself from the age of seventeen to active service upon it and to the study of ships and navigation. He led an expedition to Guiana at the age of twenty; at twenty-two, in 1596, he commanded a ship in the attack upon Cadiz, and was knighted in that campaign by Essex. Brilliant, unscrupulous, somewhat flashy as were so many of the men of his day, he was yet bold in action, bold in study, and inconceivably industrious. When one regards the evidence of his achievement as scholar in the *Dell'arcano del mare*, one finds it difficult to understand how he had also found time to become the perfect sportsman of his generation. It was written of him by a contemporary that he "was a compleat gentleman in all suitable employments, an exact seaman, a good navigator, an excellent architect, mathematician, physician, chymist and what not. He was a handsome, personable man, tall of stature, red hair'd, and of admirable comport, and above all noted for riding the great horse, for tilting, and for his being the first of all that taught a dog to sit in order to catch partridges." It may be that like many another man he was turned by the experience of sorrow from the life of action to literary exercises. Broken in pride by the Star Chamber decree, suffering from injured vanity, he enlarged the scope of his engineering interests and carried far his studies of ships and their handling. The book he brought out in 1646–1647 in four folio volumes, the celebrated *Dell'arcano del mare*, was something in the grand manner inseparable from him, but it was not so insubstantial as some of his other gestures. If it was brilliant and pretentious, it was also magnificent. The engraving of the separate plates in it, numbering well over three hundred, not counting the movable parts of the volvelles, occupied Antonio Francesco Lucini continuously throughout twelve years of seclu-

sion and required the use of five thousand pounds of copper. The book, with some additions, was brought out again in 1661 with the same plates. Perhaps no one has ever tested the huge treatise for its practicality in the work of the sea; it may be that it is too technical, too full of theories and refinements. But whether that is true or not, Dudley's volumes remain a storehouse of knowledge for the historian of the several arts and sciences that make up the life of the sea. In the great tomes he labored over so long, our Elizabethan adventurer showed himself a more splendid being than in any other concern of his life; his "Six Books of the Secret of the Sea" is the real romance of the self-styled Earl of Warwick and Duke of Northumberland.

The English Come into the Game

The English, indeed, had long since come actively into the game of subduing the sea. In the dedication to Sir Philip Sidney of the *Divers Voyages* of 1582, Hakluyt tried to impress upon his countrymen the necessity of a school of navigation in England like that maintained in the Contratación House in Seville for "the breeding of Skilfulnesse in the sea men" in the several degrees of groomet, mariner, master, and pilot. Such a school, he tells them, would result in "the saving of many mens lives and goods, which nowe through grosse ignorance are daily in great hazard, to the no small detriment of the whole realme." Sometime earlier, he goes on to say (and here we begin to suspect him of a motive in addressing his book to Sidney) he had prevailed upon Sir Francis Drake to endow a lectureship in navigation to the extent of twenty pounds a year, but the learned gentleman invited to fill the chair having demanded forty pounds as necessary to a decent living, the plan would come to a dead end unless some generous person should see fit to add the needed sum to Drake's standing offer. Clearly, Sir Philip did not respond to Hakluyt's ingenuous hint, for nothing is heard of an English school of pilotage in this generation.

But the yeast was stirring now, though in another pot; practical sailormen, the men of action, had reached for the present the limits of their capabilities in improving methods of navigation. The next great advances in the science were to issue from the brooding quiet of the study and the atelier. In 1569, Gerhard Mercator, the Flemish cartographer, published a world map, his celebrated planisphere, in which for the first time the errors in principle of the plane chart were submitted to successful correction. For the good reason that Mercator did not fully explain the mathematics of his projection, this great achievement lay almost without recognition by navigators until Edward Wright some thirty years later published a series of calculations that made the Mercator Projection practicable for use at sea. In the meantime, as John Davis witnesses in his *Seamans Secrets* of 1594, the plane chart continued, for want of a better guide, to be used for short voyages, while for voyages of longer distance, especially those involving decided change of latitude, the pilot placed his reliance upon the globe.

Mercator, Edward Wright, & the Problem of Map Projection

The discrepancies in the sea charts of the earlier period did not affect their users seriously until the era of long voyages began. The maker of a portolan chart treated the surface represented as a plane instead of as a portion of the sphere flattened upon a plane, its lines as right lines rather than as arcs of circles made to conform to the plane. For the short stretches of coast which these maps usually represented, this method was well enough, but when the cartographers began trying to cram larger and larger areas into a single chart, the small initial errors of the old charts were increased in such degree in the new as to make them useless. We have seen that this fact was recognized by many of the learned writers on navigation of the first half of the century, but neither Pirckheimer, nor Nunes, nor Cortés went beyond a theoretical discussion of the

problem, and the world of seafarers was compelled to wait another generation for Mercator to show them an easier way from land to land.

Broadly stated, the problem of map projection is to find a method of transposing the meridians and parallels, retaining their proper reciprocal relationship, from the geographic globe to a plane surface. Such a "degree net" once obtained by one method or another, the positions of places of which the latitude and longitude are known can be laid down upon the plane with accuracy. In the Mercator Projection this was accomplished by conceiving the degree net of a globe as expanded upon the inner surface of a cylinder, the parallels falling into place as horizontal parallel lines and the meridians as vertical lines crossing them at right angles. When flattened out, as one opens and flattens a rolled sheet of paper, the cylinder becomes a rectangular plane.

A visualization of Mercator's solution of the problem is offered by Edward Wright in a frequently quoted passage from his book on the prevailing errors in navigation science.

"Suppose," says the Cambridge mathematician,

> a sphericall superficies with meridians, paralels, rumbes, and the whole hydrographicall description drawne thereupon to bee inscribed into a concave cylinder, their axes agreeing in one. Let this sphericall superficies swel like a bladder, (whiles it is in blowing) equally alwayes in euerie part thereof (that is, as much in longitude as in latitude) till it apply, and ioyne it selfe (round about, and all alongst also towardes either pole) unto the concave superficies of the cylinder: each paralel upon this sphericall superficies increasing successively from the equinoctiall towardes eyther pole, until it come to bee of equall diameter with the cylinder, and consequently the meridians stil widening themselves, til they come to be so far distant every where ech from other as they are at the Equinoctiall.

If we hold in our minds for a moment the geographical globe and its net of meridians and parallels, we shall see that the parallels, running east and west, are parallel circles decreasing in circumference

as the poles are approached from the Equator, while the meridians are great circles of equal circumference intersecting one another at the poles. It is clear that in the process of expanding the globe within a cylinder by which the meridians have become vertical, parallel lines extending to infinity, the spaces between them occupied by land and water have become increasingly distorted in the horizontal direction as the Equator is left behind. To overcome this distortion it becomes necessary to expand these spaces in a vertical direction, from the Equator to the poles, in a fixed proportion to the horizontal expansion which they have already undergone. When this has been done the northern lands and spaces assume again their correct shapes and their reciprocal positions; they become "conformal" to the same lands and spaces on the globe, though, having been stretched in two directions, they differ from these in true area increasingly as the poles are approached. The Mercator Projection then is a "conformal, cylindrical projection," but the element of false scale found in it necessitates corrections in practical use. It is recognized by its straight, parallel, and equally spaced "meridians" and by its straight, parallel, and unequally spaced "parallels," with the areas between increasing vertically in depth as the poles are approached.

But despite certain obvious advantages of the new projection, it failed of adoption by mariners. The Mercator world map, though a strikingly fine representation of the earth's surface, remained, in their opinion, that and nothing more. The mathematics of its construction was so little understood that few attempted to adopt it for the small-area sectional maps which they chiefly used in the course of their business. This difficulty was not cleared up until, in 1599, Edward Wright came out of his Cambridge study with a set of rules and tables for the construction of Mercator charts. For the benefit of those who are interested in the mathematics of the great projection, we have placed in our appendix paragraphs from a navigation manual of 1800 in which are set forth the trigonomet-

ric principles that Wright employed in his construction of charts on the Mercator Projection.

The 'Great Circle' Course

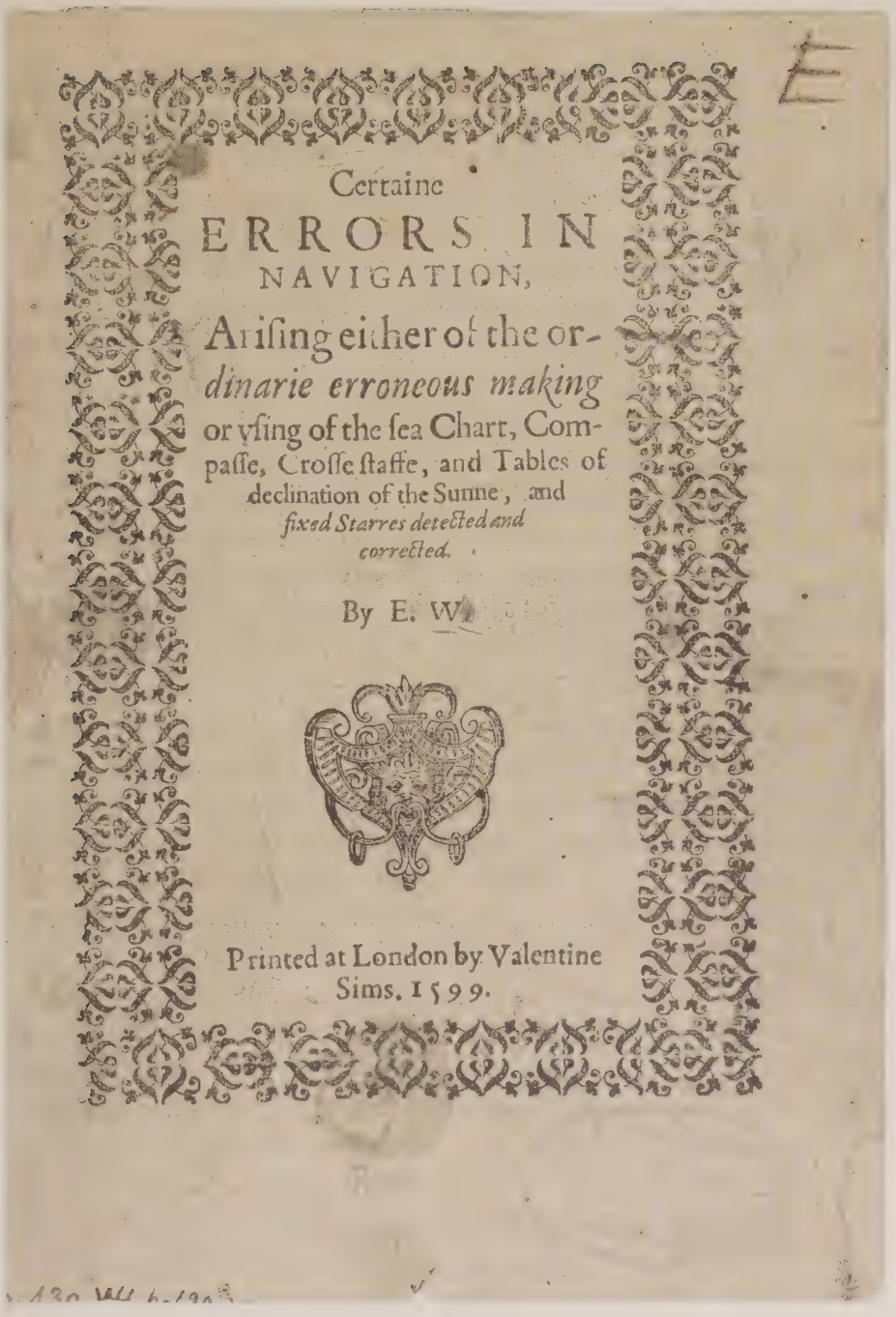
The question of great circle sailing was beginning to assume at this time great importance. The earliest record of a great circle voyage to America by an English vessel seems to be that set down by Brereton in 1602 in his *Briefe and True Relation of the Discoverie of the North Part of Virginia*. Describing that voyage, the first historian of New England wrote that the *Concord*, under command of Captain Bartholomew Gosnold, set out from Falmouth in March of that year "holding a course for the North part of Virginia [i.e. New England]: and although by chance the winde favoured us not at first as we wished, but inforccd us so farre to the Southward, as we fell with S. Marie, one of the islands of the Azores (which was not much out of our way) but holding our course directly from thence, we made our journey shorter (than hitherto accustomed) by the better part of a thousand leagues." There is evidence that Gosnold was influenced to undertake a great circle crossing by his knowledge of Verrazano's employment of that mode in his American voyage of nearly a century before his time. Strangely enough, he seems soon to have forgot his own achievement, for when, five years later, he conducted the Virginia colonists to Jamestown, he sailed southward to the Canaries, westward to Santo Domingo, and northward to Virginia.

It is not unlikely that the tedious calculation required to lay out a great circle course upon a Mercator chart was one of the factors which acted as deterrents upon the general adoption of the new projection by mariners. Even the elucidation of its principles by Edward Wright did not remove this particular obstacle to its employment. Long afterwards navigators learned that when plotted upon a chart of the gnomonic projection their great circle became

a straight line, and that when transferred to the Mercator chart so as to cut the meridians at the same angles as in the gnomonic chart, this line became a curve, representing an arc of the great circle, or shortest surface distance, they were seeking.

Edward Wright, His Book & Map

The details of Wright's contribution to the science of navigation were embodied in a notable book and a notable map of almost simultaneous publication. In the course of a voyage to the Azores in the year 1589, the ship upon which he was a passenger, though well-enough piloted, had gone far off her course. The loss of time involved and the possibility of loss of life and goods, because of the unreliability of the common chart, had so impressed the thoughtful mathematician on this occasion that he set himself the task of improving the conditions of open sea navigation. Wright's resulting calculations soon found their way, in manuscript, into the hands of a few mariners, and they were used and treasured by such men as the pilot of Drake's expedition of 1595. This proven usefulness of his method encouraged him to set it out in print; in 1599, he published in London his *Certaine Errors in Navigation ... Detected and Corrected*. Probably at the same time appeared, in the Hakluyt of 1598–1600, the celebrated world map on the Mercator Projection that we know today as the Molyneux map, or, more properly, as the Wright-Molyneux map, immortalized in literature by Shakespeare's reference to it in 1602 in *Twelfth Night* as "the new map, with the augmentation of the Indies." Wright lost something of the reward for his great service through being forestalled in publication by Jodocus Hondius, a Dutch engraver who worked with him in London, and who in 1597, issued in Holland a map of the world in which Wright's theories were expressed without credit to their discoverer. In a letter to Wright, Hondius defended himself with beguiling simplicity. "I was purposed," he wrote,



Certaine
ERRORS IN
NAVIGATION,
Ariſing either of the or-
dinarie erroneous making
or vſing of the ſea Chart, Com-
paſſe, Croſſe ſtaffe, and Tables of
declination of the Sunne, and
fixed Starres detected and
corrected.

By E. W

Printed at London by Valentine
Sims. 1599.

TITLE-PAGE of *Certaine Errors in Navigation ... Detected and Corrected*, by Edward Wright, London, 1599. Edward Wright's book revolutionized the making of charts and brought about a general improvement in sea practice. *John Carter Brown Library.*

"to have set this forth under your name: but I feared that you would be displeased therewith, because I have but rudely translated it into Latine." Surely that must be the most inept rationalization a plagiarist ever made of his conduct.

With the construction of the Wright-Molyneux map, modern cartography began, but despite the efforts of Wright, the adoption of the Mercator system of projection was slow even on the part of enlightened sailormen. New editions of his book with its tables and explanations were considered necessary in 1610 and 1657, while as late as 1722 we find Thomas Haselden doing battle for the Mercator system, as explained by Wright, in his *Description and Use of that most Excellent Invention Commonly Call'd Mercator's Chart.* The immediate cause of Haselden's book was the appearance of a globular projection devised by Henry Wilson and recommended to mariners as an improvement upon the Mercator planisphere. Haselden attacked the new chart as one which contained all the faults of the old plane chart, and characterized it, strange note of modernity, as fit only for "the Adorning of Rooms and Stair Cases." Authorities of today are equally vehement in their criticism of a projection upon which in the words of one of them, "distances and directions can neither be measured nor plotted," although to the eye it represents the picture of lands and seas with less distortion than is perceived in charts more scientifically laid down. It is astonishing to learn from Haselden's book, and from other sources, that even though mariners were using the Mercator system to some extent from Wright's time onward, the conservatism of sea customs and the general low level of mathematical education among sailors were compelling learned cartographical writers to fight for its use at sea nearly two hundred years after its first publication to the world. Although Dudley's *Dell'arcano del mare* had appeared in Florence in 1646 with certain of its charts projected upon this system, and although the *Neptune françois*, published in 1693, had adopted the Mercator Projection for its

sectional charts, the sailors of other countries as well as of England had been reluctant to take it as their guide. A century after the first publication of Dudley's noble book, charts for practical use were still being published in Amsterdam on the equidistant projection of the medieval portolan chart. This does not mean, however, that the Dutch cartographers and those who used their charts were entirely without reason. The old portolan chart was moderately effective for the delineation of areas of two or three hundred square miles, and the charts of Van Keulen, Ottens, and other eighteenth-century cartographers who clung to the old mode were highly detailed representations of short stretches of coasts and of approaches to harbors—full, learned, and sufficiently correct within their acknowledged limitations.

Several English contemporaries of Wright were at work upon the advancement of a science then becoming important to the flourishing nation. The defeat of the Armada in 1588 had aroused in England an interest in the sea that has never known abatement. The publication in London in that same year of Ashley's translation of Waghenaer's *Mariners Mirrour* gave impetus to the study of practical navigation. One of the most important works of the period was *The Seamans Secrets*, by John Davis, mariner and explorer, who, in 1594, set forth under this title a handbook of the "sweet skill of sayling," in which art, he claims, the English "are not to be matched by any nation of the earth." This book relegated Eden's translation of Cortés to the shelves of libraries, though Davis had little but practical seamanship to add to the accepted lore of the water world.

We may speak only in passing of other English writers and scientific men of this period—of Robert Norman and his instrument for recording the "dip of the needle," of William Bourne, with his several dissertations upon seamanship and naval warfare. We must dismiss with only a bare reference those mathematicians and instrument makers and practical sailing masters who were making

contributions to the science of discovery while Shakespeare and Marlowe were opening Newe Indias of another sort to the human ken. We must pass rapidly the century that separates them from Edmund Halley and his voyage to the South Atlantic in 1699 for the purpose of observing and mapping the lines of variation of the needle. Halley's findings were the basis of all later knowledge by which this essential correction to magnetic calculations is made, and the chart that he constructed remains one of the keystones of nautical science.

A Seaman's Library in 1627

It is interesting to establish a check upon the state of navigation knowledge from time to time by considering the treatises regarded as necessary for the sailor's guidance in different periods. In the time of Columbus a mariner might have in his cabin a book or books of sailing directions, a printed or manuscript book of tables of declination, a treatise on the sphere, but nothing else of the sort, for the rules of his technical practice were carried in his head. So far as we know, unless the first edition of the *Regimento do estrolabio* was issued in the closing years of the fifteenth century, there was no printed treatise on navigation science available to him. But something over a hundred years later, when the continents Columbus discovered were being explored and settled, a different situation was to be found. The English ships which sailed to New England and Virginia carried a compact little library of essential treatises. In his *Sea Grammar* of 1627 John Smith gave this list of works recommended for the cabin of a well-found ship:

Master Wrights errours of Nauigation.

Master Tapps Sea-mans Kalender.

The Art of Nauigation.

The Sea Regiment.

The Sea-mans secret.

Waggoner.

Master Gunters workes.

The Sea-mans glasse for the Scale.

The New Attracter for variation.

Master Wright for use of the Globe.

Master Hewes for the same.

The identity of these works, so well known at the time as to make unnecessary exact titles in referring to them, seems to be this:

EDWARD WRIGHT. *Certaine Errors in Navigation ... Detected and Corrected.* 1st ed. 1599; 2d ed. 1610.

JOHN TAPP. *The Seaman's Kalendar, or an Ephemerides of the Sun, Moone, and ... Starres.* 1602; 5th ed. 1615.

MARTÍN CORTÉS. *The Arte of Navigation, Conteynyng a Compendious Description of the Sphere, with the Makyng of Certen Instrumentes and Rules for Navigation.* Englyshed by Richard Eden. 1st ed. 1561; 10th ed. 1615.

WILLIAM BOURNE. *A Regiment for the Sea, Conteyning Most Profitable Rules, Mathematical Experiences, and Perfect Knowledge of Navigation.* 1st ed. 1573; 5th ed. 1611.

JOHN DAVIS. *The Seamans Secrets....* 1st ed. 1594; 4th ed. 1626.

LUCAS WAGHENAER. *The Mariners Mirrour.* [English edition of the Dutch work edited by Anthony Ashley.] 1st ed. in English, 1588; 2nd ed. 1605. (It may be that this word "Waggoner" in Smith's list is intended for any book of sailing directions, or of sailing directions and charts combined, for by this time English sailors were calling books like this one by Waghenaer—a "Waggoner.")

EDMUND GUNTER. *Canon triangulorum.* 1620; and *The Description and Use of the Sector, the Crosse-Staffe, and other Instruments.* 2 parts. 1624; originally issued in 1623 in two parts with separate titles.

JOHN ASPLEY. *Speculum nauticum: A Looking Glass for Sea-men, Wherein they may Behold a Small Instrument called the Plaine-scale.* 1st ed. 1624.

ROBERT NORMAN. *The New Attractive* ... 1576.

EDWARD WRIGHT. *Description and Use of the Spheare.* 1st ed. 1613; 2nd ed. 1627.

ROBERT HUES. *Tractatus de globis et eorum usu.* 1st ed. 1594; 1st Englished, 1638.

CHAPTER 5

Longitude and Dead Reckoning

THE STORY of man's efforts to determine his longitude at sea is one of the most painful in his slow progress towards the mastery of the world in which he lives. His failure to accomplish this feat was a fly in the ointment of scientific complacency for many centuries. To know so much and yet not to be able to fix with exactness his position in the open sea was shame and vexation of the spirit, and more, an ever-present cause of destruction of life and goods. Through the long centuries of the medieval and renaissance periods, down to the end of the eighteenth century, he continued to determine his east and west position by that process of calculating distances and directions which we know as dead reckoning.

The problem was greatly complicated by the mariner's ignorance of the correct linear measurement of a degree. The length of a degree measured upon a parallel varied, furthermore, with the distance of the parallel from the Equator, a fact that introduced what must have seemed an unnecessary complication into the seaman's life. The world breathed more freely after it had learned the measurement of its own girth through the determination by Richard Norwood in 1635 of the actual length of a degree of latitude, or a degree of longitude on the Equator, as about 69.5 statute miles. But that discovery did not solve the greatest difficulty of life at sea. The mariner continued to find his longitudinal position by the tedious keeping of records throughout every watch, to be specific by (a) measuring at intervals his rate of speed; (b) transposing rate into nautical miles; (c) marking upon his traverse board the distances and angular directions of his several courses; (d) calculating the absolute distance gained by the aid of his traverse tables;

and finally, (e) transposing that distance into terms of degrees and marking the position thus attained on the chart at the correct latitude of the ship when last determined. The difficulty of attaining accuracy by such a method is realized fully when we examine some of the instruments upon which he depended in his calculations.

The Log & its Appurtenances

As early as 1579, we find Richard Eden, in the dedication of his *Very Necessarie and Profitable Booke Concerning Navigation*, a translation of a treatise by John Taisnier, writing hopefully of a device he had seen described in a work by Jacques Besson, a French engineer resident in England. As Eden described it, quoting, probably, from Besson's *Theatrum instrumentorum* of about 1569, this was "An Artifice not yet divulgate or set forth, which placed in the pompe of a shyp, whyther the water hath recourse, and moved by the motion of the shyp, with wheeles and weyghtes, dooth exactly shewe what space the shyp hath gone." "By which description," Eden continues, "some doo understand that the knowledge of the longitude myght so be founde, a thyng doubtless greatly to be desyred, and hytherto not certaynely knowen...." This instrument was, of course, some form of mechanical log, but many generations were to pass before practical sailors were willing to place confidence in any device for measuring rate besides the ancient, well-tested log and line.

The word "log" bears a literal relationship to the nature of the instrument used by sailors of the early day, for the wooden object dropped over the side of the ship was intended to float without perceptible progress like a log on the surface of the water, while a line attached to it was paid out from the moving vessel. The operation of the device is easy enough to comprehend once this distinction between the old log and the new is understood, that is, that the old log lies relatively stationary on the surface of the water in the manner of a marker, while the ship makes off, paying out a measur-

ing line attached to it; the mechanical log, on the contrary, attached to the ship by a fixed line, moves with the ship, and its self-recording rotator is kept in motion by the drag of the water against its blades. The common log and its several parts and appurtenances comprise these simple features: the log-ship or log-clip, the log-reel, the log-line, and the log-glass. The chip is a solid wooden quadrant, weighted along its arc so that it will float in an upright position. The arrangement of peg and three cords, called the bridle, by which the chip is attached to the log-line compels it to float broadside on to whatever drag may be exerted by the weight of the line. The log-line is a light rope knotted at intervals of 47 feet, 3 inches, a measurement between knots that bears the same relation to the 6080 feet of a nautical mile as 28 seconds bears to the 3600 seconds of an hour. The log-glass is designed to empty itself in 28 seconds, and if during this time seven knots have passed through the boatswain's hands, the ship has progressed $7 \times 47\frac{1}{2}$ feet, or in other terms, it is moving at the rate of 7×6080 feet, or seven nautical miles, an hour. From the employment of this method of double measurement; that is, measurement of distance and time, arises the common, incorrect, but perfectly understood habit of saying a ship is "sailing 7 knots an hour" when in fact she is sailing 7 knots in 28 seconds. Because of this short-hand statement of the concept of rate of speed, the term "knot" has become casually accepted as a synonym for the unit of measurement known as the nautical mile.

Prime Meridians of Earlier Days

It is necessary to recall the fact that the very method of stating longitude familiar to us today is of modern evolution. The Royal Observatory at Greenwich was established only in 1675, and it was not until 1766 that the British *Nautical Almanac*, with its table of lunar observations based upon the position of Greenwich, established that place as the prime meridian of the English world. For

half a century before this time, it is true, English mariners had been learning to state their longitude in degrees east or west of that point. So close to our own period, however, as 1716, in the *Almanack* of Daniel Travis for that year, the longitude of Boston is stated as 315°, a calculation based upon the eastward position of that city with reference to the island of St. Michael in the Azores. At that time, however, and for almost a century afterwards, longitude was more generally calculated eastward from the island of Ferro in the Canaries as the prime meridian, a practice as old as the geographical system of Claudius Ptolemy. For obvious reasons the ancient geographer had reckoned his longitude only in the eastward direction, and had naturally chosen Ferro, the westernmost land known to him, as his starting point. The custom of stating all longitude as east longitude from the meridian of Ferro persisted almost to the nineteenth century, even though for a time many European cartographers, convinced that the line of no magnetic variation ran through the island of St. Michael, made use of the meridian of that place as their reference point. From habit and convenience the meridian of St. Michael was sometimes used for this purpose even after Gellibrand, in 1635, had calculated the secular variation of the needle. Diversity in the choice of prime meridians became greater in the eighteenth century than ever before. There seem to have been in that period no national preferences, and cartographers, without regard to race, graded their maps, at will, east of Ferro, east and west of Ferro, east of St. Michael, east of the Peak of Teneriffe, east and west of London, east and west of Paris, and, in strictly North American maps, east and west of Philadelphia. It is easy to understand that the lack of uniformity in the choice of a prime meridian and the practice, so long continued, of calculating all longitude in the eastward direction alone must have been factors contributing to the difficulty of the ordinary mariner in determining his longitude.

Chapter 5

The Search for an Infallible Method of Determining Longitude

From the beginning of the sixteenth century, when voyagers were extending their cruises westward to America and eastward to India, the problem of determining longitude took possession of men's minds as never before. It became an obsession of science, and many methods were proposed, examined, and discarded. The chief of these were by the variation of the compass, by lunar distances, and by a timekeeper. The first-named method was cast aside as useless when it was discovered that the degree of variation of the compass was in itself irregularly variable in every place from year to year, and that the agonic line, or line of no magnetic variation, was not a meridian but a curve deviating from the north and south line. Even before this time the practical experiments of João de Castro, a Portuguese navigator, had convinced many as early as 1538, that there was no possibility of calculating longitude by the magnetic variation. The method of lunar distances had more to recommend it. In his Ptolemy of 1514, John Werner, inspired perhaps by Regiomontanus, described a method of using tables showing the angular distances at a fixed point on shore, such as Greenwich became in later days, between the moon and certain fixed stars. Gould writes in *The Marine Chronometer*, "These distances can also be observed, by means of the sextant, on board ship, and, by interpolation, the Greenwich time corresponding with that distance can be taken out of the tables. The local time of observing such 'lunar distances' can be obtained by the ordinary observations, and the difference, of course, gives the longitude of the ship." It was in this fashion that the problem was approached by such mariners as were not content with dead reckoning from Werner's time until the closing years of the eighteenth century. Indeed it was only in 1907, when a more nearly correct solution had been practiced for a century and a half that the lunar distance tables finally disappeared from the British *Nautical Almanac*. Scientifically sound though it was, the method

in practice was slow, inexact, and so complex in calculation that it never became practicable for the ordinary mariner. It was, indeed, several generations after Werner's time before any consistent trial was made of the lunar distance method. Most men of the sixteenth and seventeenth centuries were content to let the matter be, convinced that the ability to determine longitudinal position at sea had been withheld from mankind through the inscrutable purpose of the Creator, though one that we know of believed that the operation of the dreadful ordinance had been waived in his favor. Richard Eden wrote, with an event of 1557 in mind: "Sebastian Cabot on his death bed tolde me that he had the knowledge thereof [i.e. determining longitude] by divine revelation, yet so, that he myght not teache any man. But I thinke that the good olde man, in that extreme age, somewhat doted, and had not yet even in the article of death utterly shaken of[f] all worldly vayne glorie." Nearly a century later, in 1632 Champlain recorded in his little treatise on navigation the pious conviction that the good God did not intend that man should be able to determine longitude at sea. But governments and individual scientists showed themselves less willing than sailors to accept quietly the supposed Divine inhibition. As early as 1598, Philip of Spain offered a cash reward and a pension of many thousand ducats to the discoverer of a method for determining longitude. Private individuals in various lands, and the governments of Holland, Venice, and France proposed rewards for a similar purpose, and finally the people of Great Britain became aroused to the need for action. In 1714, Parliament appointed a Commission that soon became known as the "Board of Longitude," and offered a premium of £20,000 to the successful inventor of a method by which a ship's longitude could be determined at any time within half a degree. This action was brought about by an accumulation of maritime disasters grave enough to force the issue. One of these was the loss in 1711, at the mouth of the St. Lawrence, of eight ships and nine hundred men in Sir Hovenden Walker's fleet of ships of war and transports through an error of forty-five minutes in the calculation of the fleet's position. Once

more we find ourselves thinking of the might have been and the course of empire. So slight a thing as an error "in the logg," as Sir Hovenden Walker described it, brought to nothing vast plans for the conquest of Canada by this joint expedition of New England and royal forces in the summer of 1711. Because of the failure of this attack, the French remained masters of Canada for nearly half a century longer. The Canadian disaster recalled forcibly to Englishmen the wrecking, four years earlier, of the squadron of Sir Cloudesley Shovel, in which four ships and two thousand men met their fate on the Scilly Isles with the dead reckoning of most of the ships indicating a clear and open sea ahead. Here was government property lost and soon there followed government action.

There is no doubt that the invention and perfecting of a mode of determining longitude was stimulated and hastened by the proposed reward. From 1714 to 1828, the Commission continued its hearings and gave out in premiums and appropriations the sum of £101,000. Accomplished scholars in Europe and obscure amateurs of mathematics in distant American colonies alike devoted their energies to bringing about a solution of the problem. During the first half of the eighteenth century, "the discovery of the longitude," Gould says, "passed into common English speech as expressing a thing of practical impossibility." It crept into literature as a stock jest at human aspiration and credulity. Swift, Goldsmith, and Hogarth had their fling at it. Swift, in a serious mood, wrote that he had been told the discovery was "a thing as improbable as the philosopher's stone, or perpetual motion";[9] satirically he wrote in his "Ode for musick on the Longitude":

> The longitude mist on
> By wicked Will Whiston
> And not better hit on
> By good master Ditton

9. F. Elrington Ball, ed., *The Correspondence of Jonathan Swift, 1690–1712.* (London, 1910), vol. 1, p. 324: Swift to Archbishop King, 29 March 1712.

and in the "ritornello" to this "recitativo" gave license to his wit in an ingenious bit of rhyming, jovial and gratuitously insulting, and of such signal bawdiness in tenor and expression as to account for its absence from the usual collections of the Dean's works. Arbuthnot, writing to Swift, called down a pox upon Whiston because that gentleman's seriously offered solution resembled so closely a humorous proposal he was about to make in one of his papers that the point of the joke was dulled. But the joke, as events soon demonstrated, was really on the funny men.

The Lyttle Clocke

As early as 1530, the mathematician and astronomer Gemma Frisius announced in his book *De principiis astronomiae* a method of his own invention by which, he wrote in Eden's translation, "can I fynde the longitude of regions although I were a thousand myles out of my attempted course & in an unknown distance." The new method was simply to take advantage of the increasing mechanical skill by which "Lyttle clockes" were then being made that "often tymes move continually for the space of xxiiii houres." The rest was simplicity. On leaving any port of which the longitude was known, the mariner had only to set his "lyttle clocke" by the time of that place and afterwards to see that it was kept running. Thereafter, any day in the voyage, the hour of the fixed reference point indicated by this clock compared with the hour determined as local ship's time by the daily observation of the sun at noon would give a difference in time that could quickly be stated in terms of degrees east or west of the known starting point. In theory no method for the effective determination of longitude could have been easier to understand or to practice, and if clockmakers had been better the story had been shorter. For two centuries longer, however, men continued to struggle with the tedious and intricate observation of lunar distances, for because of the imperfect state of the horological science in this period even the wonderful twenty-four hour

clock that Gemma Frisius commended could not be used satisfactorily in an operation so delicate as this in which minutes on the dial might mean several critical miles in the reckoning. Nevertheless, the principle was irrefutable, and during the ensuing two centuries many skilled clockmakers and scientists continued to make better and better clocks, always with the idea of constructing one for use at sea which would be so nearly perfect that the very constancy of its error might be depended upon as one of the factors in calculating longitude.

John Harrison & the Chronometer — Q.E.F.

Nearly two hundred years after the proposal by Gemma Frisius of the clock method, John Harrison, an English clockmaker, urged by ambition and by the hope of obtaining the Parliamentary reward, began to work at the problem of determining longitude by means of a prime meridian and an accurate timekeeper. In 1726 he produced a clock improved by two inventions of his own—a gridiron pendulum compensated for changes of temperature, and a "grasshopper escapement"—which varied less than a second a month in the fourteen years for which a record was kept of its performance. In 1735, with another clock, even more carefully built, he was demanding the reward from the Commission, but failing still to convince its members completely of the merit of his invention. For the next twenty-six years he was constructing improved clocks under encouraging grants from the Commission. It is evident that his efforts were known to the learned of the time and watched by them with a great deal of interest. Benjamin Franklin, for example, made a visit to "Harrison's to see his Longitude clock" one of his first pleasures after his arrival in London in 1757. Harrison's great improvement in horology seems clearly to have been one of the topics of the town in the later years of its inventor's experimentation. Finally in November, 1761, the British ship *Deptford* set out for Jamaica carrying Harrison's fourth clock, in charge of his

son William, and various official witnesses to an experiment which was to be remembered as one of the most notable of modern times. Harrison's No. 4, as this historic mechanism has come to be designated, was in reality a large watch greatly more convenient and more cunningly constructed than his earlier cumbersome clocks. Nine days out the ship's log by dead reckoning showed a longitude of 13°50′ west of Greenwich, but the calculation based upon the clock gave the position as 15°19′. William Harrison defended the inerrancy of his father's clock and said that the island of Madeira would be sighted next day. This event occurred as predicted by the clock's guardian, and when in due course, after a voyage of more than eight weeks' duration, the ship arrived at Jamaica, "the timekeeper was found," in Gould's words, "after allowing for its rate of going, to be five seconds slow, corresponding to an error in longitude, ... of 1¼′ only," roughly, a distance at that latitude of less than one geographical mile. With this happy result of the test, the chronometer, as the ship's clock is called in our day, came into its own as the natural, easy, and exact method of determining longitude at sea. Eleven years later, after other trials even more convincing, and after a struggle with the obdurate Commission, some members of which were still thinking of "lunar distances" as the correct solution of the ancient problem, Harrison received the great reward. Though "Longitude Harrison" must always have the glory of having demonstrated the practicability of determining longitude accurately by a timekeeper, the modern chronometer itself is less indebted to him in its mechanical features than to Pierre Le Roy, a French clockmaker who, working independently, constructed in 1766 the marine clock from which the present ship's clock descends. In the chronometer, a clock mounted upon gimbals, effectively compensated for friction and for changes of temperature, Champlain would have perceived a sign that "le bon Dieu" had at last relented, that no longer was man to lack the satisfaction of knowing his longitude at sea.

Conclusion

This is the last invention of basic importance in the slow business of subduing the sea. Gnomon, cross-staff, astrolabe, quadrant; compass, log, and chronometer; *periplus*, *portolano*, and Coast Pilot; Marinus of Tyre, portolan charts, Mercator charts, and charts of Admiralty and Coast Survey; Nunes, Wright, and Bowditch—we have run swiftly in this review a course of thirty painful centuries. From Solomon confessing ignorance, to us in the pride of our knowledge is a long tale of years, a long record of toil and effort, of failure, trial, and success. Sometimes a cynic thought invades us and we ask to what end the stubborn courage, the groping of mind, the battling of body, that have made possible this mastery of the sea. We read John Masefield's poem contrasting the ivory-laden quinquireme of Nineveh with the dirty British coaster and its cargo of coal and pig-lead and cheap tin trays, and reading, regret desperately a world denuded of color and stately grace. But that, surely, is a contrast of surface things. It does not matter what strange new ships ply the waters nor what their corded bales contain. Beneath them the sea is still the sea, inviting men with smiling face, awing them with swift ruthlessness, challenging them as ever with promise of distant isles, unknown to Ptolemy, whence even now may be brought ivory and apes and peacocks for man's delight.

APPENDIX I

Blundeville's Description and Mode of Using Cross-staff and Astrolabe.[10]

A BRIEFE DESCRIPTION OF THE MARINERS ASTROLABE AND THE VSES THEREOF.

The limbe of the Mariners Astrolabe is traced as you see with three Circles, making two spaces to containe therein the degrees and numbers of altitude: and these Circles are divided by two crosse lines called Diameters, and cutting one another in the very Centre of the Astrolabe into 4 equall parts of which quarters the uppermost on the left hand towards the Ringle is onely marked with degrees and numbers, as you may see in the figure: In which figure the perpendicular Diameter signifieth the Zenith, or the line of South and North, at the upper end whereof is fastned the Ringle or handle. And the other overthwart Diameter signifieth the Horizon, the one end whereof on the left hand signifieth the East point, and the other end on the right hand the West point. And to this Astrolabe (as to all other) doth belong a ruler or Diopter, which as you see hath at ech end a square tablet pearced with two holes, the one greater and the other lesser, the greater to looke thorough with your eye, to take the altitude of any star or of the Sun being so darkened by some cloud as though it casteth no shadow, yet it may be seene with the eye: And the lesser hole is for the Sunnes beame to passe thorough when he shineth cleare, & some Astrolabes are devided in like maner on both sides of the Zenith, and have two Diopters, whereof the one is pearced with a great hole, and the other with a smaller hole to serve to such purposes as is above said.

The use of this Astrolabe is onely to take the altitude of the Sunne at any time of the day, or of any fixed starre or Planet in the night, in such

10. From Blundeville's *Exercises* (London, 1597), pages 328, 297, and 329.

sorte as is before taught in my description of Maister Blagraue his Astrolabe, in the third and fourth Proposition thereof.

HOW TO TAKE THE ALTITUDE OF THE SUNNE, OR OF ANY STARRE.

To take the altitude in any time of the day when the Sunne shineth, you must turne your face and also the left Tablet or Pinule of the Diopter towardes the Sunne, holding the Astrolabe by the ring with your right forefinger or middle finger being somewhat bowed, in such sort as the Astrolabe may hange plumbe, and then with your left hand lift the Diopter up and downe untill the Sun with his beame do justly streeke through both the holes of each Pinule of the Diopter, so as you may see the shadow of the two holes of the upper Pinule to play upon the two holes of the nether Pinule, then marke upon what degree of altitude the thinnest edge or Fiduciall line of the Diopter falleth in the outermost skirt or border of the backe of the Astrolabe, for that is the Sunnes altitude for that present. But if the Sunne be covered with a cloud, so as it shineth not cleare inough to cast any shadow, & yet so as it may be seene with the eye, then hang the Astrolabe by the ring uppon your right thumbe, and turning your face towardes the Sunne, lift up your hand with the Astrolabe so high, as by mooving the Diopter with your left hand up and downe, you may with your right eye (the other being shut) see the Sunne through the greater holes of both the Pinules of the Diopter, and marke uppon what degree of altitude the upper end of the Diopter falleth, and that is the altitude of the Sunne at that time, and in this manner you must also take in the night season, the altitude of any starre.

A BRIEFE DESCRIPTION OF THE MARINERS CROSSE STAFFE.

This staffe consisteth of two foure square rulers of woode, whereof the one is called the yarde, and the other the Transame or Crosse: And the yard containing in length most commonly three quarters of a yarde

is the longer peece, and is devided into 90. unequall degrees: for from 10. to 90. the degrees doe grow lesser and lesser, and the Transame containing for the most part but one third part of the yard, is cut with a square hole in the middell, so as it may runne up and downe upon the yard, & some Transames have two running vanes to be set at what widenes you list, to take thereby the distance of any two starres.

THE VSES OF THE MARINERS CROSSE STAFFE.

The use of the Mariners staffe chiefly consisteth in two points, that is, to knowe thereby the altitude of the Sun in the daytime, or of any starre in the night season, and the other is to know thereby the distance betwixt any two starres.

The first is thus done, having put the staffe or yarde through the square hole of the Transame, set the end of the yard which is marked with 90. to your eye, laying that end upon the uper point of your cheeke bone keeping your legs close together, and having directed the other end of the yard towards the sunne or star whose altitude you seeke, moove the Transame to and fro or up & down, until you may see with the onc eye (winking with ye other) the one end of the Transame to meete just with the centre or middell of the Sun or star, & the other end to touch ye Horizon both at one instant, and that degree of the yard which the square edge of the Transame cutteth, wil shew how high the Sun or star is at that present: And in taking the altitude of the sun or of any star, remember alwales to hold the yard so level as it may be a just Parallel to ye Horizon, for so shal you take the altitude ye more truly.

APPENDIX II

Description of Hadley's Quadrant or Sextant of Reflection.[11]

Mr. John Hadley was the first publisher of the description of the *Quadrant of Reflexion*, for measuring angular distances; and the instrument still bears his name, although it has been ascertained that Sir Isaac Newton invented a similar instrument many years before, but never made it public: one of our countrymen, Mr. Thomas Godfry, of Philadelphia, had also contrived an instrument on the same principles some time before Hadley made known his discovery.

In the adjoined plate we have given a figure of the quadrant; the principal parts of which are, the graduated arch BC, the index D, the vernier, the index glass E, the horizon glasses G and H [*sic* for F], the dark glasses or screens H, and the sight vanes K and I.

The graduated arch BC contains only 45°, but is to be exteemed as 90°, and so divided, because by the double reflexion the angle is doubled. Each degree is divided into three parts of 20 minutes each; and the arch is numbered from the right to the left, beginning at 0° and ending at 90°. The index D is a flat bar moveable round the centre of the instrument, where is fixed the index glass E; at the other end is fixed the vernier scale: from the bottom of the index a piece of brass turns up against the back of the instrument, with a screw to it, serving to fasten the index against any division. The vernier is a small narrow slip of brass or ivory, fixed to that part of the index which slides over the graduated arch; its use is to subdivide the arch into minutes, and in common quadrants the breadth of it is equal to 7 degrees of the arch, which on the limb of the quadrant is divided into 21 equal parts, but on the ver-

11. From Bowditch's *New American Practical Navigator*. First Edition. (Newburyport, Mass., 1802), pages 136–137.

nier is only divided into 20 equal parts; consequently each division of the scale of the vernier is greater than a division of the limb by 1/20 part of one of these divisions, that is, by one minute. Therefore the difference between the first division of the vernier and limb is 1′; the difference of the second division is 2′; the difference of the third division is 3′, &c. And these divisions of the vernier are marked in such manner, that having found the lines which coincide on the limb and vernier, the mark corresponding will be the excess of the measured angle above that division of the arch of the quadrant which immediately precedes the mark 0 of the vernier. Thus if the mark 0 of the vernier pointed exactly to the first division of the arch between 60 and 70, the angle would be 6° 20′; if it pointed to the second division it would be 6°40′; if the mark 0 had passed just beyond this second division, 6°40′, and the mark 7 of the vernier was found to touch a mark of the arch, the angle would be 6°47′.

The index glass E is a piece of glass truly ground, silvered on the back, and fixed in a brass frame perpendicularly to the index: its use is to receive the rays proceeding from any object, and reflect them to the horizon glasses F and G. At the back of the brass frame of this glass, are two screws serving to adjust the glass perpendicularly to the index.

The horizon glasses F and G are smaller pieces of ground glass, one part of which is silvered, and the other part open or unsilvered, in order to look at an object through it. These are set in frames and placed perpendicularly on the limb at G and F, with screws at the back to adjust them: their use is to receive the rays of any object reflected from the index glass, and again to reflect them to the eye through the holes of the sight vanes K and I. The sight vane K, and the horizon glass F, are used in the common or *fore observation*, where the observer's face is turned towards the objects; the others are used in the *back observation*, in which the observer's back is turned towards the objects. The sight vane K, of a common quadrant, has two holes in it; that farthest from the plane of the instrument is used in observing any object in the unsilvered part of the glass; the other is used in observing the object in the silvered part.

APPENDIX III

Edward Wright's Principles for the Construction of a Chart on the Mercator Projection.[12]

Mr. Wright, in 1599, published the principles of the True Sea-Chart, and how to construct it on the following principles, viz.

That the distance between any two meridians at the equator is in proportion to their distance in any parallel of latitude, as the radius is to the co-sine of that latitude:

That any part of a parallel of latitude is to a like part of the meridian, as the radius is to the secant of that parallel:

And that the distance of any parallel of latitude from the equator is equal to the sum of the secants of all the arches between the equator and that parallel.

From these principles, Mr. Wright set about forming a table, by the continual additions of secants of all the parallels of latitude, beginning with one minute, which he made radius, and thereto adding the second parallel of 2 minutes, and to the sum of these two, the secant of 3 minutes, &c. The table thus formed, is that which is commonly called the Table of Meridional parts, by means of which a true nautical chart may be constructed, called Mercator's Chart, and all the cases in Wright's, commonly called Mercator's Sailing, constructed and calculated.

Newes of the Complement of the Art of Navigation, London, 1609, pages 13 and 14:

And although it may be objected, that not only Sir Humfrey Gilbert, and Richard Polter, & other, haue attempted the reformations of these imperfections, but also that M. Edw. Wright has lately perfected the

12. From Moore's *New Practical Navigator* (Newburyport, Mass., 1800), the second American from the thirteenth English edition, page 90.

same, so that all errors and absurdities are by him reformed. I answere & freely confesse, that the said M. Wright hath exceedingly wel deserved of Nauigation, and specially in that projection of the sea Mappe by him deuised, (according to which, the Mappe commonly annexed to the volumes of our English Discoueries, and the great quarter Maps published at Amsterdam by Iodocus Hondius, anno 1602 are framed).

APPENDIX IV

A Note on the Practice of Tacking

The small number of references to tacking in early and mediaeval literature has caused much misunderstanding as to the period of its adoption as the habitual practice of seamen. An extreme statement occurs in William Wood's *Elizabethan Sea-Dogs,* where is found the paragraph:

> In 1539, too, came the discovery of the art of taking, by Fletcher of Rye, Henry's shipwright friend, a discovery forever memorable in the annals of seamanship. Never before had any kind of craft been sailed a single foot against the wind. The primitive dugout on which the prehistoric savage hoisted the first semblance of a sail, the ships of Tarshish, the Roman transport in which St. Paul was wrecked, and the Spanish caravels with which Columbus sailed to worlds unknown, were, in principle of navigation, all the same. But now Fletcher ran out his epoch-making vessel, with sails trimmed fore and aft, and dumbfounded all the shipping of the Channel by beating his way to windward against a good stiff breeze. This achievement marked the dawn of the modern sailing age.[13]

By examining the accessories of navigation and the rigging and construction of early vessels with thoughtful care, other students of the subject have reached a conclusion at variance with that set forth above. The learned Nordenskiöld carries back the practice at least a century earlier than the time of Fletcher of Rye. "The power of sailing against wind and wave," he writes,

> and of building ships fit for this purpose, is naturally a main condition of navigation by sails, and its discovery forms an epoch in the history of navigation of little less importance than the introduction of steam in the 19th century. I have, however, tried in vain to get in-

13. William Charles Henry Wood, *Elizabethan Sea-Dogs: A Chronicle of Drake and his Companions.* Chronicles of America, vol. 3. New Haven, Conn.: Yale University Press, 1918, 1921; reprinted Washington, D.C.: Ross and Perry, Inc., 2002), 26.

formation as to when sailors first learnt this art. So far as I can make out, it is not spoken of in the few accounts of Greek and Roman voyages that are preserved; the Greek and Latin languages do not even possess a special name of their own for taking. Even in the literature of the Middle Ages this was of beating up against the wind is seldom mentioned, unless we may take it that the stories of the dreadful power possessed by the Vikings of putting in, even with a contrary wind, to the coasts that they wishes to spoil, allude to the northern sailor's knowledge of the art of taking. Under these circumstances, great interest attaches to the direction given on one of the sheets of Bianco's atlas of 1436, how sailors ought to keep their dead reckoning, i.e., how, when taking, to calculate the main course of the vessel according to the different courses made during the watched. For this purpose, in the upper corner of the map-sheet in question a traverse-table is inserted (*toleta de marteloio*) with a short direction (*raxon de marteloio*) how to use it.

As long ago as 1783, the Italian writer Formaleoni, examining the traverse-table of the Bianco chart referred to be by Nordenskiöld, concluded that its calculations were based upon the trigonometric functions. We are thus lead by Nordenskiöld and Formaleoni to assume that the Venetian sailors could sail into the wind as early as 1436 because we find them possessed at that time of a mathematical system of determining their dead reckoning in the face of divers courses. To assume this is to assume that the practice must have been familiar to them for a long time before 1436, for a highly complex system of calculation does not come to birth without a long period of gestation, and, in this case, would not have come into being at all unless the problem it proposed to solve were already existent.

Describing the ships of Queen Hatshepsut of Egypt, 1500 B.C., John Forsyth Meigs writes:

> They have one mast only, a single spar, and on this one sail, there being a yard at the foot as well as head.... The two yards show they could lie close to the wind; perhaps not as close as modern square riggers; 6 points but about 7."[14]

14. John Forsyth Meigs, *The Story of the Seaman: Being an Account of the Ways and Appliances of Seafarers and of Ships from the Earliest Time Until Now.* Philadelphia, Pa., London, J. B. Lippincott Company, 1924. 1,28.

In another section, Meigs writes again of tacking:

> It has been pointed out that ships from an early date used rigging both running and standing like what we employ. They could sail by the wind and work to windward probably from the time sails were first spread; if the wind hauls and sail lifts what so natural as to haul in the sheet or brace up the yard of a square sail, if it hauls quickly and enough to catch the sail aback the ship tacks herself. The yards at head and foot of sails of Hatshepsut's ships show craft of her day sailed near the wind.[15]

There are allusions to beating to windward in early times; Theognis born about 570 B.C. writes,

> Wearied and sick at heart in seas of trouble
> I work against the wind and strive to double
> The dark disastrous cape of poverty

And Sophocles about 500 B.C. says,

> Whoever manages a vessel having drawn firm
> The sail-rope gives no way; he upsetting her ...

There are mentions of sailing close-hauled in later days, as for example in 200 B.C. in Plautus[16] and 75 B.C. in Catullus.[17]

The ability of Egyptian ships to maneuver under varying conditions of wind is discussed by Charles Boreux[18] and the structure of sail, mast, yards, and cordage of Egyptian ships of the period is illustrated in the same work.[19]

The evidence of several writers cited in the foregoing note seems to indicate that from the earliest times tacking has been regarded as a prerequisite to successful navigation under sail.

15. *Ibid.*, 1, 200.

16. Plautus, Bohn ed., 11, 425.

17. Catallus, Bohn ed., 12. These classical allusions were called to my attention by Professor Benjamin C. Clough of Brown University.

18. Charles Boreux, *L'art de la navigation en Égypte jusqu'à la fin de l'ancien empire* (Paris, 1925), 377–378, 385.

19. *Ibid.*, 264–265, 364, 368, 380–383.

PART II

Some American Contributions to the
Art of Navigation
1519–1802

ORTHODOXAL NAVIGATION.

OR,

The Admirable and excellent ART of

ARITHMETICALL

GREAT CIRCLE-SAILING,

Inlarged and applied to places of all

SITUATIONS,

And many difficulties removed, and sundry things now added, that were never published before.

Whereby, Sailing by an Arch of the great Circle, extended from any one Place, to any other Place, (where possible and convenient) is made easie to the understanding of those of mean capacity, and ready to demonstrate with facility, And suiting with the Marriners haste, by a speedy dispatch, when he hath but a short opportunity.

Together

with a new and true

PARADOXAL CHART.

By BENIAMIN HUBBARD, late Student of the Mathematicks in *Charls Towne* in *New-England*.

London, Printed by *Thomas Maxey*, for *William Weekly* of *Ipswich* in Suffolk, and are to be sold by *John Rothwell*, at the Bear and Fountain in *Cheap-side*. 1656.

Some American Contributions to the Art of Navigation 1519–1802*

INTRODUCTORY NOTE

AN OCCASIONAL departure from strictness of definition will be remarked in this account of certain American contributions to the art of navigation. Now and then, for example, one of the writers mentioned in the course of it will seem to be American only through the slimmest of circumstances, and frequently books of seamanship or maritime law and custom will intrude upon the manuals of navigation science, the sailing directions, and the charts which form the main theme of the discussion. The reader's indulgence is asked for this element of irresponsibility in an essay which, after all, is but an exploratory entrance into a new field of study.

IMAGE OPPOSITE: *Orthodoxal Navigation* (1656). Benjamin Hubbard's book on great-circle sailing was composed, in part at least, while its author was resident in Massachusetts. *John Carter Brown Library.*

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* This paper was read at the April, 1946, meeting of the Massachusetts Historical Society. It was first published separately in Providence by the Associates of the John Carter Brown Library in 1947 in advance of its publication in *Proceedings of the Massachusetts Historical Society*, volume 68, pp. 72–112.

CHAPTER I

The Spanish-American Contributions

IT IS INEVITABLE that this discussion should begin with a selection of materials of Latin-American origin. It was natural enough that the American of the South should take a part in the production of works on navigation, for, as has been said many times, it was the demand for surer and safer voyaging to the East Indies and to the western continent which in the sixteenth century provided a notable stimulation to the advancement of maritime science by the mathematicians and pilots of Spain and Portugal.

Martín Fernández de Enciso was a Spanish lawyer whose career in America seems to have begun at Santo Domingo at some time before the year 1508. For five years thereafter, and longer, it may be, he served prominently in official positions, chiefly upon the mainland of Central and South America. His exploits and misadventures are found in the history books. What is of concern here is his publication at Seville in 1519 of a work entitled *Suma de geographia*,[1] which combines between its covers a brief manual of navigation principles, long mistakenly believed to be the first of that species of book, and an extensive geographical and political description of the continents and countries of the world. Because its American section, comprising eighteen small-folio pages, was based in part upon his personal experience of the areas described, it is possible without too great a strain upon the facts to accept it as an American contribution. The true reason for bringing it into the discussion, however, is that it provides a base line from which to start. Its pages represent a formal effort, the first of its

1. Henry Harrisse, *Bibliotheca americana vetustissima* (New York, 1866), No. 97; José Toribio Medina, *Biblioteca hispano-americana* (Santiago de Chile, 7 volumes, 1898–1907), 1, No. 56.

kind, to guide the mariner in his passage from port to port along the eastern and northern coasts of South America, the Central American coast and the islands of the West Indies. Enciso's book was republished with some revision in 1530 and 1546. In 1541 the whole work, upon the basis, it has been said, of the edition of 1519,[2] was translated into English by Roger Barlow, amended and augmented, and presented to Henry VIII with a plea for its publication. Henry failed to heed the plea, and the manuscript remained unpublished until it was put into print by the Hakluyt Society in 1932.[3] The long interval between composition and publication minimizes the importance of Barlow's work except as an historical document. It is more to the present point to record the fact that the American portion of Enciso's book was translated into English by John Frampton and in 1578 published in London under the title, *A Briefe Description of the Portes ... of the Weast India*.[4] Frampton's version of Enciso is one of the supreme rarities. No copy of it is recorded in England, but it is owned in this country by the Henry E. Huntington, the New York Public, and the John Carter Brown Libraries.[5]

One of the most interesting of the several hundred books and other printed pieces which proceeded from the press of New Spain in the sixteenth century was the *Physica speculatio* which in 1557 was published in Mexico City, the work of Alonso de la Vera

2. A brief account of Enciso's career in America is found in Eva G. R. Taylor's introduction to Roger Barlow, *A Brief Summe of Geographie.* Publications of the Hakluyt Society, Second Series, vol. 69 (London: The Hakluyt Society, 1932).

3. For the source of Barlow's translation, see page 71, note 8, above.

4. *Check-List ... of the Library of Henry E. Huntington* [*English Literature to 1640*] (New York, 1919), 150; Alfred W. Pollard and Gilbert R. Redgrave, *A Short-title Catalogue* (London, 1926), No. 10823.

5. William M. Bishop, *A Checklist of American Copies of "Short-Title Catalogue"* Books (Ann Arbor, Mich., 1944), No. 10823. The New York Public Library copy is imperfect. When Wroth gave this address in 1946, the John Carter Brown Library had not yet acquired its copy and a third copy was then found in the private library of Dr. A. S. W. Rosenbach of Philadelphia.

Cruz, Augustinian friar, great scholar and simple Christian.[6] In the pages of that first work of physical science produced in the western hemisphere were chapters devoted to astronomical theory and to theories concerning the winds and the tides. Though this is the sort of knowledge upon which rests the science of navigation, the book would not be mentioned here if only a single edition of it had come from the press. But that was not the case. This Mexican work so commended itself to contemporary scholarship in Spain that the second and third editions of it were printed at Salamanca. No copy of the second edition of 1562 is available for examination in this country, but copies of the third edition, published in 1569,[7] are to be found in several libraries of the United States. In that edition, among numerous extensive revisions and additions, are two chapters wherein are given the latitudes and the distances from one to another of some eighty points on the coasts of the American continents from Labrador southward to the Strait of Magellan and thence northward to the coast of Lower California.[8] Because compass bearings from place to place are not given in the Vera Cruz list, it was hardly sufficient to serve as a practical pilot, or book of sailing directions, but its assemblage of the fundamental data here described suggests the existence of a lively interest in sixteenth-century Spanish America in the problems of coastal navigation.[9]

6. Medina, *La Imprenta en México,* 8 volumes (Santiago de Chile, 1907–1912), I, No. 33.

7. The Salamanca editions of 1562 and 1569 are described in Medina, *Biblioteca hispano-americana, I, Nos. 190 and 211.*

8. The new material occupies pages 220–225 in the edition of Salamanca, 1569.

9. My attention was called to this addition to the *Physica speculatio* of 1569 by Professor Louis C. Karpinski of the University of Michigan in 1924. See John Carter Brown Library, *Report to the Corporation of Brown University, July 1, 1925* (Providence, R.I., 1925), 15–16. Before Professor Karpinski's discovery of these passages the interest of the book to the historian of American coastal navigation had not, I believe, been noticed.

A very different kind of importance is associated with another production of the Mexican press, the *Instrucion nauthica* of Diego García de Palacio, printed in Mexico City in the year 1587.[10] In this work, the product of a press operating in a distant outpost of civilization, is comprised a manual of the science of navigation which may be included without apology in the series of books of its sort which, since the *Regimento do estrolabio* was published at Lisbon about 1509, had been coming every few years from the studies of scholars and the cabins of practical navigators of Portugal and Spain. García de Palacio had already published in Mexico in 1583 a work on military science.[11] He was born in Spain into a family of mariners, and his early studies had been directed towards the theory and practice of seamanship and navigation. Among his first employments in America, whither he came in the government service, was the building of ships, and especially experimentation in the building of ships with native American woods. He led in Guatemala and Mexico a life which must have been of interest to himself and which was certainly of importance to his time and place. He came briefly into the pages of world history when, in September, 1587, he was appointed to the command of the expedition which was organized at Acapulco to oppose Thomas Cavendish, then making himself obnoxious to the Spanish of the West Coast.[12] But before the avenging fleet could get well started Cavendish had made his memorable capture of the *Santa Ana* and had sailed far into the Pacific vastness. These circumstances raised

10. Medina, *La Imprenta en México*, 1, No. 106.

11. *Dialogos militares*. See Medina, *La Imprenta en México*, 1, No. 95, incorrectly numbered 98.

12. Joaquin García Icazbalceta, *Bibliografia mexicana del siglo XVI* (Mexico, 1886), Nos. 90 and 97, record the titles of the two works of García de Palacio here mentioned and in his note to No. 97 gives an interesting biographical sketch of their author. Through inadvertence he wrote that it was Sir Francis Drake's attack upon the West Coast which García de Palacio was commissioned to repel. Medina, *La Imprenta en México*, 1, 257, picked up the error and gave it wider currency.

INSTRVCION

NAVTHICA; PARA EL BVEN

Vſo, y regimiento de las Naos, ſu traça, y
y gouierno conforme à la altura de Mexico.
Cõpueſta por el Doctor Diego garcia de
Palacio, del Cõſejo de ſu Mageſtad,
y ſu Oydor enla Real audiẽ-
cia de la dicha Ciudad.

Dirigido, al Excellẽtiſsimo Señor Don Aluaro Manrrique, de
çuñiga, Marques de Villa manrrique, Virrey, Gouer-
nador, y Capitan general deſtos Reynos.

Con licencia, En Mexico, En caſa de Pedro
Ocharte. Año de 1587.

The *Instrucion nauthica* of Diego García de Palacio, the earliest American navigation manual, contains a section on shipbuilding and a glossary of nautical terms. *John Carter Brown Library.*

a question among the contemporaries of García de Palacio as to whether he would have proved himself as capable in executing the tactics of warfare as he had been in formulating them. Speculation upon that question would be unprofitable.

The *Instrucion nauthica* of García de Palacio is a book of genuine interest in the long list of navigation manuals. Its superior was not to come from the pen of an American writer until Nathaniel Bowditch performed his great work of revision, elaboration, and restatement in 1802. It contains not only the instructions usually found in the manuals but in addition an illustrated section on shipbuilding and a glossary of contemporary nautical terms. Important and useful in its time, it continues to be important to the historian of the sea. Many will recall the frequent and always illuminating references made to it by Samuel Eliot Morison in his *Admiral of the Ocean Sea*.[13]

Well within the scope of this discussion as previously defined is a treatise by Juan de Hevia Bolaños, a Spanish lawyer resident in Peru, on that aspect of the law known in English as the "law merchant," and in earlier days and other lands as the *lex mercatoria*. The *Labyrintho de comercio terrestre y naval* was published for the first time at Lima in 1617.[14] In his address to the reader Hevia Bolaños informs us that this is the long-promised second and concluding part of a comprehensive book of legal principles and precedents, the *Curia philipica*, which he had published at Lima in 1603.

In this Peruvian edition of 1617, the *Labyrintho de comercio* represents, it is believed, the earliest American work in which a substantial portion of the text is devoted to a statement of the law and custom regulating sea-borne commerce, an aspect of human relationships with roots deep in the past of man's extra-mural activities. The ancient world knew a forerunner of this book in the

13. In the two-volume edition (Boston, Mass.: Little Brown, 1942), vol. 1, pp. 186–7, 199, 222, 238, 249, 258.

14. Medina, *La Imprenta en Lima.* 4 volumes. (Santiago de Chile, 1904–1905), 1, No. 73; John Carter Brown Library, *Report ... 1929*, 10–11.

"Laws of Rhodes," and among the important legal creations of the Middle Ages were the French "Judgments of Oléron," the Swedish "Ordinances of Wisby," and the Catalan "Book of the Consulate of the Sea." The creation of these codes through the centuries and the gradual tacit acceptance of their authority by sailors and merchants mark a process in social evolution, the progress of man's emergence from the brutality and chaos of primitive neighborhood concepts. The community of ideas they set up and even their vocabulary became factors in the development of trade between nations as a normal activity of mankind. The earliest American addition to this ancient literature took its place among the more authoritative works on the subject of the law merchant. It was reissued separately at Madrid in 1619, but after that it appeared many times from 1644 to the middle of the nineteenth century as the second part of the *Curia philipica*.[15]

In the year 1740 there was published in London a book entitled *A Geographical Description of the Coasts, Harbours, and Sea Ports of the Spanish West-Indies ... Translated from a Curious and Authentic Manuscript, Written in Spanish by Domingo Gonzales Carranza*.[16] In its "Preface" and its "Advertisement" appeared assertions to the effect that it was the translation of an incomplete manuscript book of sailing directions recently brought to England by a gentleman long a prisoner of the Spanish at Havana. It is probable that the book was published in time to be of service to the English naval

15. Medina, *La Imprenta en Lima*, I, No. 16. For later editions of the *Curia philipica*, with or without the *Labyrintho de comercio* as its second part, see the indexes of volumes II–V of Medina, *Biblioteca hispano-americana*. See also the fuller list in Antonio Palau y Dulcet, *Manual del librero*, 7 volumes. (Barcelona, 1923–1927), IV, 34–35. An evidence of the importance attributed to the work of Hevia Bolaños is its appearance in the brief list of fourteen titles which Étienne Cleirac cites as his principal references in his work on the law merchant entitled *Les us, et coutumes de la mer* (Rouen, 1671). Cleirac's list of sources and his historical introduction lend a special interest to his work.

16. Joseph Sabin, *A Dictionary of Books Relating to America*. 29 volumes. (New York, 1868–1936), III, No. 11030.

officers in the prosecution of that truly nasty conflict which is called the War of Jenkins's Ear. Whether the statement concerning the origin of the book was true or not, it would have been good advertising policy for its publisher to claim it as deriving from a Spanish manuscript. Because of the scarcity of the printed book, however, and the absence of records of such a manuscript as that described, there could have been few opportunities for confirmation of the publisher's claim until, some months ago, the John Carter Brown Library acquired a manuscript with the following title and declaration of authorship: "Mapa de las Derrotas, y otras Observaçiones a las Corrientes, con la Variacion de la Abiyade Marear, hechas por el Capitan D^{n} Domingo Gonzalez Carranza."[17] Comparison showed beyond question that the English book, *A Geographical Description*, was indeed a translation of large passages in the Spanish manuscript of Domingo Gonzalez Carranza, thus verifying the claim made two centuries earlier by its London publisher. Further comparison showed either that the manuscript brought to England by the prisoner from Havana was fragmentary or that the English translator made only a selection of what seemed to him its important passages. The Carranza manuscript contains a much more extensive text than the English book, and its geographical scope is larger. Another difference between the "Mapa de las Derrotas" and the English translation is that the Spanish original contains a whole section devoted to the niceties of shipbuilding with particular application to the construction of spars and sails.

The sailing directions of the Carranza manuscript cover the same area of land and sea portrayed upon a chart in the John Carter Brown Library constructed in 1740 by the naval lieutenant Antonio de Matos that is the area of the Gulf, the Caribbean, and the Atlantic Coast as far north as Cape Hatteras.[18] Joined in their use, the two must have constituted an aid to navigation of the first im-

17. John Carter Brown Library, *Report ... 1946*, 31–36.
18. John Carter Brown Library, *Report ... 1944*, 28–33.

portance. The Spanish governmental ban upon the printed publication of maps and written guides to the coasts of its colonies prevented these two works from coming into world-wide usefulness. One may not doubt, however, that many manuscript copies of the Carranza pilot were to be found in the cabins of Spanish ships in the American trade and of Spanish-American ships engaged in coastal traffic. It is permissible to designate both these works, the Carranza pilot and the Matos chart, as American contributions because, obviously, neither could have been created without long and close first-hand acquaintance with those coasts on the part of their authors.

This account of the Carranza sailing directions, more complete than other known manuscript guides to the Gulf and Caribbean waters, brings to a close our consideration of Latin-American productions composed as aids to navigation. In succeeding pages the discussion will concern itself chiefly with contributions by residents of the English colonies of North America.

CHAPTER 2

Some Questionable Cases

IT SEEMS DESIRABLE to mention briefly two books in English and one in French which, by the exercise of leniency in definition, might be regarded as American contributions to the science of the sea. The first of these is Captain John Smith's *An Accidence or the Path-way to Experience. Necessary for All Young Sea-men*, London, 1626,[19] and its greatly enlarged revision, *A Sea Grammar*, of the next year. The second of the English authors with historic American background who wrote effectively on the subject of navigation and its problems was Richard Norwood, a man whose residence of more than forty years in Bermuda occurred, for the most part, after his composition of *The Seaman's Practice* of London, 1637.[20] In that work was set forth in detail the survey of the earth's surface from York to London by means of which was finally determined the length of a degree on the great circle.

The books of Smith and Norwood are mentioned here for the sake of the record. It seems unnecessary to argue the propriety of their inclusion or exclusion from this discussion. There remains to be considered, however, another of these borderline cases, for which a somewhat stronger claim may be made. It will seem to

19. Wilberforce Eames in Sabin, xx, Nos. 82812 and 82839. See also under these titles in Sabin for other editions.

20. Pollard and Redgrave, *A Short-title Catalogue*, No. 18691. A copy is in the British Museum and another in the Folger Shakespeare Library, Washington, D.C. For Norwood's life in Bermuda and an account of his maps of Bermuda, see *The Journal of Richard Norwood Surveyor of Bermuda*, with introductions by Wesley F. Craven and Walter B. Hayward (New York, Scholars' Facsimiles & Reprints, 1945). On pages lxi–lxii are listed sixteen editions of *The Seaman's Practice* in a bibliography compiled by William A. Jackson, librarian, The Houghton Library, Harvard University.

many that if ever a man deserved the designation "American," that man was Samuel de Champlain, founder of New France and resident within it for nearly thirty years, explorer of American coasts and maker of maps elucidating their trends and outlines. Champlain published at Paris in 1632 a treatise in which he summed up his thirty-eight years of experience at sea, chiefly in American waters. The *Traitté de la marine et du devoir d'un bon marinier* first appeared in conjunction with the Paris, 1632, edition of *Les Voyages*.[21] It is a simple and modest little book compounded of principles of seamanship and navigation practice, devoted particularly, the author writes in his address to the reader, to "the matter of reckonings and how to proceed in constructing charts by the aid of the mariner's compass." If this book be permitted in a list of American contributions to the art of navigation, to it must certainly be added the surveys of the Quebec, Port Royal, and other Canadian harbors and the great map, "Carte Geographique de la Nouvelle Franse faictte par le Sieur de Champlain...," published with the Paris, 1613, edition of *Les Voyages*. Later, in the 1632 edition of *Les Voyages*, came the more extensive and more important "Carte de la nouvelle france."[22] All these were aids to navigation. Among the greatest of the cartographical monuments in the Library of Congress is the original manuscript of a Champlain map of 1607, "Description des Costs ... de la Nouvelle France."

21. Henry P. Biggar, ed., *The Works of Samuel de Champlain*. 6 volumes. (Toronto, The Champlain Society, 1922–1936), VI, 253–346.

22. The two maps are reproduced in I, Plate LXXXI, and III, Plate X, in Biggar, ed., *The Works of Samuel de Champlain*. Both facsimiles have been located in the portfolio of maps accompanying the work rather than in the volumes to which they relate.

CHAPTER 3

A New England Book of the Seventeenth Century

THE FIRST English-American book to be discussed is virtually unknown to bibliographers and historians of navigation. The truth is that only three copies of the book, two in England and one in the United States, have so far been located. This work was the production of a one-time citizen of Massachusetts. *Orthodoxal Navigation* of London, 1656, was composed by one Benjamin Hubbard, who described himself on the title page of his book as "late Student of the Mathematicks in Charls Towne in New-England." [23]

Benjamin Hubbard was born in Suffolk, England, in 1608, the son of James and Naomi (or, possibly, Elizabeth) Hubbard. Benjamin emigrated to Boston in 1633, where on August thirtieth he and Alice, his wife, were admitted to membership in the First Church of Charlestown. He was made a freeman in 1634, and the church records show five children born to him and his wife before the end of the year 1644. The Charlestown Land Records define the position of his dwelling house and of his fifty acres of land. In June, 1637, he "solemly admonished of his failing, for being in company

23. *Orthodoxal Navigation. Or, the Admirable and Excellent Art of Arithmeticall Great Circle-Sailing ... Together with a New and True Paradoxal Chart.* "By Benjamin Hubbard, late Student of the Mathematicks in Charls Towne in New-England. London, Printed by Thomas Maxey, for William Weekley of Ipswich in Suffolk, and are to be sold by John Rothwell, at the Bear and Fountain in Cheapside. 1656." Copies of the book are found in the British Museum, the John Carter Brown Library, and (I am informed by Mr. Donald G. Wing of the Yale University Library, editor of the *Short-Title Catalogue, 1641–1700*) in the library of the Royal Society, London. The John Carter Brown copy lacks the six plates, which have been supplied in facsimile from the British Museum copy.

with James Browne and the rest, and often drinking of the strong water bottle with them, and not reproving them." There exist arid spaces in the broad reaches of mathematical science. Even its most devoted students, it seems, occasionally need to clear their minds of sines, cosines, tangents, and secants. Hubbard became involved also in the Antinomian controversy and went so far in 1637 as to write Roger Williams for his "helpe and furtherance" in a plan to be his neighbor "in some place neere adjoyning." It was probably late in 1644 that Hubbard left his home in Charlestown for England, for on February 25, 1644/45, he wrote from London to Governor John Winthrop in terms which indicated a recent voyage. He observed in this letter that he had not yet "made tryall" of his "invention concerning Longitude before artists, but a time is appointed for it." In a letter of the same day to John Winthrop, Jr., Hubbard refers somewhat vaguely to what may have been the expected trial of his invention. In 1645 he was joined in England by his wife and children, and as early as 1648 he is described as minister at Copdock, Suffolk. The date of his death is given as October 27, 1660.[24]

It was inevitable, perhaps, that Hubbard's treatise, *Orthodoxal*

24. I am much indebted to Mr. Samuel Eliot Morison for knowledge of certain facts concerning Hubbard derived from the following sources: Edward Warren Day, *One Thousand Years of Hubbard History* (New York, 1895), 50; *New England Historical & Genealogical Register*, XXIII, 191, and 111, 77 and 93; *Third Report of Record Commissioners of Boston* (1878), 55; *Massachusetts Bay Records*, I, 199 and 209; *Records of Court of Assistants*, II (1630–1644), 68; Richard Frothingham, *History of Charlestown* (Boston, Mass., 1845), 73; *Collections of the Massachusetts Historical Society*, Third Series, I, 20–21, and Fifth Series, I, 335–336; *Winthrop Papers*, III, 509, and V, 9–10.

It may be added that the Union Catalogue of the Library of Congress records a treatise with a portentously long title which may be briefly stated as *Sermo secularis. Or, A Sermon to Bring to Remembrance the Dealings of Jehovah with this Kingdom of England ... ab ... 1547 ... ad Praesentem Annum, 1647 ... Preached at Belstead near Ipswich, July 4, 1647.* "By Benjamin Hubbard, Preacher of the word of God at Copdock in Suffolke. London, 1649." There is a copy of the sermon in the McAlpin Collection, Union Theological Seminary, New York City.

Navigation, should have passed straight from the printing house into oblivion. It dealt with restricted aspects of the subject, and its solution of the problem with which it was chiefly concerned did not admit of easy and universal application. None the less, one of the procedures its author developed and advocated has a peculiar interest in the history of open-sea navigation. The sea chart in common use today is the chart on the Mercator projection which goes back to the great world map constructed by Gerhard Mercator in 1569. In 1599 Edward Wright explained to the world the principle of the Mercator projection and, as is commonly said, made it practicable for the use of mariners.[25] But the mariners who were benefited by Wright's formulas and explanations were necessarily those who possessed more than a small degree of mathematical knowledge. As late as 1722 Thomas Haselden was urging upon mariners the use of the Mercator projection and defending it against reactionaries then proposing other and less scientific forms of chart.[26] The characteristic of the projection which for a long time prevented its extensive use in navigation was that a great-circle course could not be plotted directly upon it. It was necessary to lay down the great circle upon a globe and from thence transfer it to the Mercator planisphere, plotting it thereon by the angles it made with the successive meridians of the globe. But most globes were so small that these angles could with difficulty be accurately measured. A tedious mathematical process, beyond the abilities of most mariners, was required for their correction.

Today's simplification of this procedure is found in the use of a planisphere upon the gnomonic projection. A great-circle course plotted directly upon a gnomonic chart takes the form of a straight line. Transferred to the Mercator chart this straight line becomes a curve cutting each meridian at a different angle. The straight line

25. Edward Wright, *Certaine Errors in Navigation ... Detected and Corrected* (London, 1599). This notable book was reprinted in 1610 and 1657.

26. Thomas Haselden, *The Description and Use of that Most Excellent Invention Commonnly Call'd Mercator's Chart* (London, 1722).

of the gnomonic chart becomes the great-circle arc of the Mercator.[27] Gnomonic charts today are provided by the United States Hydrographic Office to aid in this operation.

The significance of Hubbard's book is that it set forth an early attempt to provide a chart which would perform the service of today's gnomonic chart in the procedure of laying down a great-circle course upon a chart of the Mercator projection. It is not easy to determine whether the remedy he proposed for this fundamental difficulty was entirely original with him or a development of the theories of his generation. He asserted in his dedication to the Masters, Wardens, and Assistants of Trinity House that he had learned much from his predecessors, notably John Davis[28] and Richard Norwood,[29] but that some things "they either quite omitted, or treated of so obscurely, that my shallow capacity could not understand them," a confession which considerably increases the self-esteem of many of us of this day who have pored over the elliptical explanations in which the old masters of navigation seem to take for granted that their readers were looking over their shoulders as they wrote or that they were gifted with the power of reading between and behind the lines of their texts as well as the lines themselves. It must be added that when Hubbard came to make his own explanations, he seems not greatly more lucid than those he criticized, but it is certainly true that he tried earnestly to establish clear rules of procedure and that he had in mind a definite

27. See explanation with diagrams in Charles H. Deetz and Oscar S. Adams, *Elements of Map Projection* (Washington, D.C., United States Government Printing Office, 1938), 101–103, and also page 140, where the gnomonic projection is defined as a "perspective projection upon a tangent plane, with the point from which the projecting lines are drawn situated at the center of the sphere."

28. John Davis, *The Seamans Secrets*, reprinted in *The Voyages and Works of John Davis*, Albert H. Markham, Editor (The Hakluyt Society, London, 1890), from the edition of 1607. The book was entered in the *Stationers' Register*, 3 September 1594. A copy of an edition dated 1595 is in the New York Public Library.

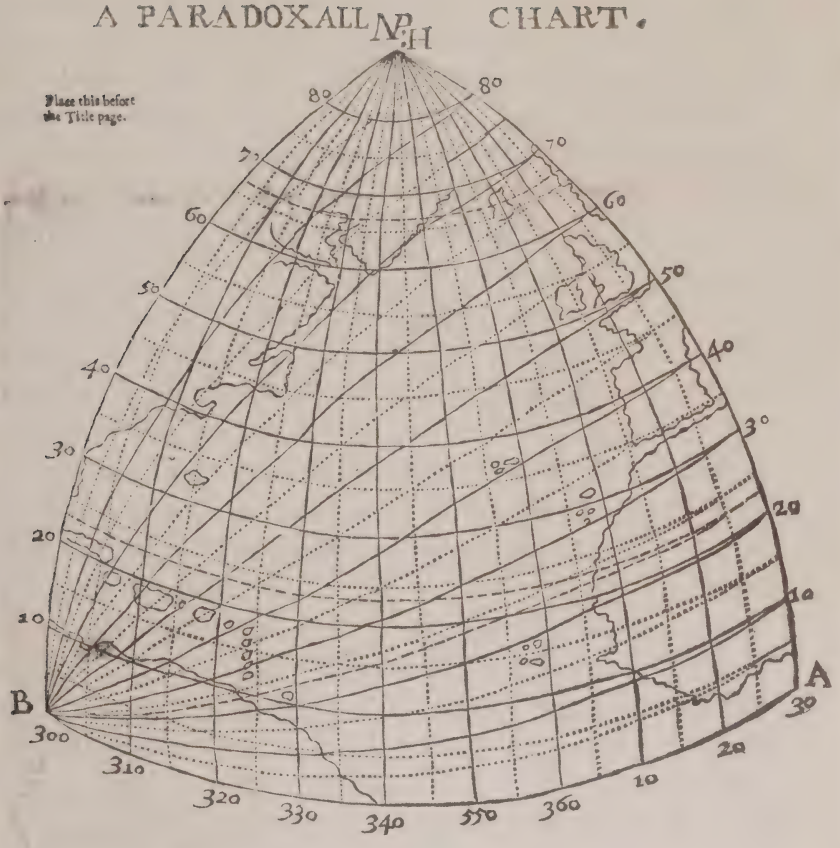
29. Richard Norwood, *The Seaman's Practice* (London, 1637). See Note 20 above.

method which he explained by charts, diagrams, and tables of his own construction.

Hubbard's chief contribution to the practice of sailing upon the great circle was the construction of a chart which he called "a new and true Paradoxal Chart." That chart represented the superficies of a spherical triangle embodying one-eighth of the surface of the earth. Upon the chart thus constructed he laid down eighteen great-circle courses. These were computed by the principles of spherical trigonometry, and so far as Hubbard's projection is correct, the courses laid down are correct. His belief was that one or another of the eighteen great circles which he constructed would take the mariner to a landfall within easy distance of his chosen destination. The desired great circle could be selected and then lifted from the paradoxal chart and correctly plotted upon the Mercator chart. In this procedure was to be found the whole point of Hubbard's learned system. Disregarding its exactness or inexactness, we are able to say of him that he gave development in his book to the principle now universally followed in laying down a great-circle course upon a chart of the Mercator projection, that is, its earlier plotting upon a chart of such a projection as would ensure its representation of an arc of the great circle when the transference to the Mercator had been made. Hubbard's solution was to employ for this initial plotting his paradoxal chart; the customary solution today, as already said, is the use for this purpose of a chart upon the gnomonic projection. One of the plates in the Hubbard book is a table of angles which his great circles make with the Equator, providing a ready means for transferring the course from the paradoxal to the Mercator chart.[30]

Even though it has been completely forgotten and is not included

30. Mr. David A. Jonah of the Brown University Library, formerly of the Department of Mathematics, has greatly aided my comprehension of Hubbard's work. It would be improper, however, to make Mr. Jonah responsible for whatever inadequacy may appear in the explanation of the Hubbard system given in the text.



In this Paradoxal Chart, the Angle at H above represents the North Pole, marked also with NP.

The lower side from B to A represents a quarter of the Equator, or Equinoctiall Line.

The side B H. part of the Meridian at Longitude 300 degrees.

The side A H part of the Meridian at Longitude 30.

And by the sides B H and A H are figured the degrees of Latitude, with their Parallels, The Tropick of *Cancer*, at 23 deg. 30 min. And the Artick Circle at 66 deg. 30 min.

Then from the Angle B to the Meridian A H there be 18 Arches of great Circles.

I applied it to these degrees of Longitude containing that eighth part of the Superficies of the Terrestriall Globe, wherein long voyages are now most frequently made.

A PARADOXALL CHART. The plotting of a great-circle course as set forth in Benjamin Hubbard's *Oxthodoxal Navigation* (1656). *The John Carter Brown Library.*

in the usual lists of works on navigation, Benjamin Hubbard's book may not be dismissed as unimportant. It is, in fact, one in the line of treatises, beginning with Wright's *Certaine Errors*, which finally established the methods leading to the present position of the Mercator chart in the practice of navigation.

CHAPTER 4

The Cartographers Begin their Work

THE MOST elaborate special map produced in the English colonies in the seventeenth century was Augustine Herrman's *Virginia and Maryland*, published in London, engraved by Faithorne, in 1673.[31] The story has been told many times of that memorable production by the soldier of fortune who, after experiences elsewhere in America, settled in New Amsterdam in 1643 as merchant and trader, and died in Maryland in 1686 as lord of Bohemia Manor, a tract of vast acreage.[32] His success as merchant and landowner and his varied services to the communities in which he lived are overshadowed in the minds of most of us by his achievement as the maker of what is commonly called, without elaboration, the "Herrman Map." This notable work was first of all a land map, but such is the topography of tidewater Virginia and Maryland that any map of the area must include Chesapeake Bay and its tributary rivers. In constructing his map Herrman brought within its scope southern Pennsylvania, southern New Jersey, Delaware Bay, and part of Delaware River. Taking into account the circumstance that Delaware Bay, like the Chesapeake, was beginning to carry a good deal of foreign and local traffic, he gave full attention to his survey of its shoals and channels. Upon his map are recorded soundings and shoals inside both the great bays, along the Atlantic

31. P. Lee Phillips, *The Rare Map of Virginia and Maryland* by Augustine Herrman (Washington, D.C., 1911); Edward B. Mathews, *The Maps and Map-Makers of Maryland* (Baltimore, Md., 1898), 368–386; John Carter Brown Library, *Report ... 1930*, 10–15. A facsimile of the map was issued by the John Carter Brown Library in 1941.

32. For accounts of Herrman's life, see, in addition to the works cited in the preceding note, Earl L. W. Heck, *Augustine Herrman* (Englewood, Ohio, 1941), and Thomas Capek, *Augustine Herrman of Bohemia Manor* (Prague, 1930).

coast of New Jersey, Delaware, and Maryland, and far up the chief rivers emptying into the Chesapeake. Interested on a large scale in the tobacco trade of Maryland and Virginia, interested in the development of lands in the Delaware River area, Herrman naturally wished to make access to those parts easier for European vessels. The Herrman map thus comes within the category of the maritime chart.[33] Between 1673 and 1752 at least eight derivatives or adaptations of the great map were published in England and France. The original of London, 1673, is known today only by the copies in the British Museum and the John Carter Brown Library. The John Carter Brown Library possesses also, in its Blathwayt Atlas, a manuscript version of the map, gorgeously portrayed on vellum in gold and color sometime between 1670 and 1680.

If there was expressed earlier in this discussion some little doubt as to the effect upon his contemporaries of Benjamin Hubbard's *Orthodoxal Navigation* no such consideration arises in connection with the contribution of the New England cartographer now to be named. Cyprian Southack was a young man of twenty-three years when in 1685 he came to Massachusetts as an officer of the coast guard maintained in New England waters by the British government. Sixty years later he died in Boston after a lifetime of service to the British colonial administration, as well as to the local government, as commander of the *Province Galley* which policed the New England shores from Long Island Sound to Newfoundland.[34] It

33. In a separate note to himself, Lawrence recorded "NJ Map of 1677 has virtually the same Delaware Bay soundings etc., as printed Herrman map. In fact this may well have been done by Herrman (Didn't Penn suggest this?) Has also entrance to New York. The entrance to New York by way of Sandy Hook is laid down with shoals and Soundings on the Robert Ryth, however, was not printed."

34. A brief sketch of Cyprian Southack, written by Mrs. Clara (Egli) LeGear, is found in the *Dictionary of American Biography*. [For more recent references, see Clara Egli LeGear's "The New England Coasting Pilot of Cyprian Southack" *Imago Mundi* (1954) no. XI, pp. 137–144; Sinclair Hitchings' "Guarding the New England Coast: The Naval Career of Cyprian Southack" in Colonial Soci-

was Southack's distinction that what he learned in the course of his laborious life of coastal voyaging he recorded in cartographical form for the use of others—data concerning coastlines, soundings, shoals, currents, courses, and all the other elements of danger and safety which have their place upon the maritime chart. As early as 1694 he constructed charts, known only in manuscript form, entitled "A Draught of Boston-Harbor" and "A Draught of New-England, Newfoundland, Nova-Scotia, and the River of Canada," and by the time of his death in 1745 he had made from his own surveys some twenty-five sea charts, large and small, chiefly of the coasts of New England, Nova Scotia, and the broad area of the Gulf of St. Lawrence.[35] The exception to this statement regarding the scope of Southack's interest was his first printed production, [*A New Chart of the English Empire in North America*] of Boston, 1717, an essay in cartography which covers the entire coastline of the Atlantic and the Gulf of Mexico from Labrador to the mouth of the Mississippi.[36] South of Long Island this map is useless for sailing purposes; north of the Sound it charts the coastal waters on a larger scale and with a greater degree of detail than is embodied in the charts of the several editions of *The English Pilot: The Fourth Book* which preceded it. To be assured of this fact one has only to compare the Boston map of 1717 with the charts for this area in Southack's own copy of the first *English Pilot: The Fourth Book* of London, 1689, a valued possession of the Massachusetts

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ety of Massachusetts, *Seafaring in Colonial Massachusetts* (Boston, Mass., 1980), pp. 43–65, and the biographical sketch in the *Dictionary of Canadian Biography*, vol. III (1740–1771) available on line at http://www.biographi.ca/.]

35. A manuscript list of Southack's maps, compiled by Mrs. LeGear, is on file in the Library of Congress, the John Carter Brown, and other libraries.

36. *Notes on the Southack Map* (Boston, Mass., 1717) to accompany the *Facsimile* issued by the John Carter Brown Library (Providence, R.I., 1942). See also John Carter Brown Library, *Report ... 1942*, 26–38, and Lawrence C. Wroth and Marion W. Adams, *American Woodcuts and Engravings, 1670–1800* (Providence, R.I.: Associates of the John Carter Brown Library, 1946), No. 5, for discussions of this map, its maker, and its engraver, Francis Dewing.

Historical Society. One may feel assured that Captain Southack studied this book with particular intensity. Until he had made his own coastal configurations and offshore soundings, its representations were to him a matter of life or death. But one is amused to find that later when, in all probability, he felt that he knew more than the book could tell him about the New England waters, he began to utilize the volume for another purpose. He realized one day in 1697 that the blank reverses of its maps would serve excellently for the rough drafts of the letters his maritime business required him to write. Evidently he had never been told as a boy that he must not write in his book, because thenceforth this volume became his letterbook. Few institutions own the first edition of *The English Pilot*: *The Fourth Book*; only one owns that work combined with the official correspondence of Captain Cyprian Southack.

Despite obvious defects in the presentation of data, Southack's map of 1717 commends itself to historians because it was a political document as well as a work of cartography, carrying inscribed upon its face an address which strove to awaken the colonies to the danger of the French encroachment. It commends itself to antiquarians and historians of art, furthermore, because it is the first map to be engraved in line upon copper in the United States. It was the work of Francis Dewing of Boston, one of the earliest individuals to practice the craft of line engraving in this country.

The chief of Southack's productions was *The New England Coasting Pilot*, an atlas of eight sheets published in London in 1720, and thereafter, with additions, in 1734, about 1758, and 1775.[37] His name came prominently before the maritime world when the editors of *The English Pilot*: *The Fourth Book* included in their edition of 1721, and twenty-three times thereafter in the ensuing seventy-three years, his chart entitled, "The Harbour of Casco Bay and Islands Adjacent." A more ambitious Southack chart than that re-

37. No. 6 in Mrs. LeGear's manuscript list of Southack charts. See Note 35 above.

lating to Casco Bay, "A Map of the Coast of New England, from Staten Island to the Island of Breton," seems to have been published first by John Senex, of London, about 1744.[38] That chart, too, was long a feature of *The English Pilot*: *The Fourth Book*, appearing in it first in 1775 and thereafter six times before the end of the century.

Looking back upon the achievement of Cyprian Southack as briefly outlined in the preceding paragraphs, one may not doubt that he performed a definite service to the science of navigation. In his own time and for fifty years after his death, certain of his charts were at all times in the hands of English and American mariners. Because of the inclusion of these charts in *The English Pilot: The Fourth Book* the seal of authority was stamped plainly upon them. If one may use sentiment as has sometimes been done, to bridge the breaks in a line of descent it is not difficult to think of Southack as the ancestor of the United States Coast Survey, which today carries on a continuous charting and recharting of our waters.

38. A copy of the original Senex edition is in the New York Public Library.

CHAPTER 5

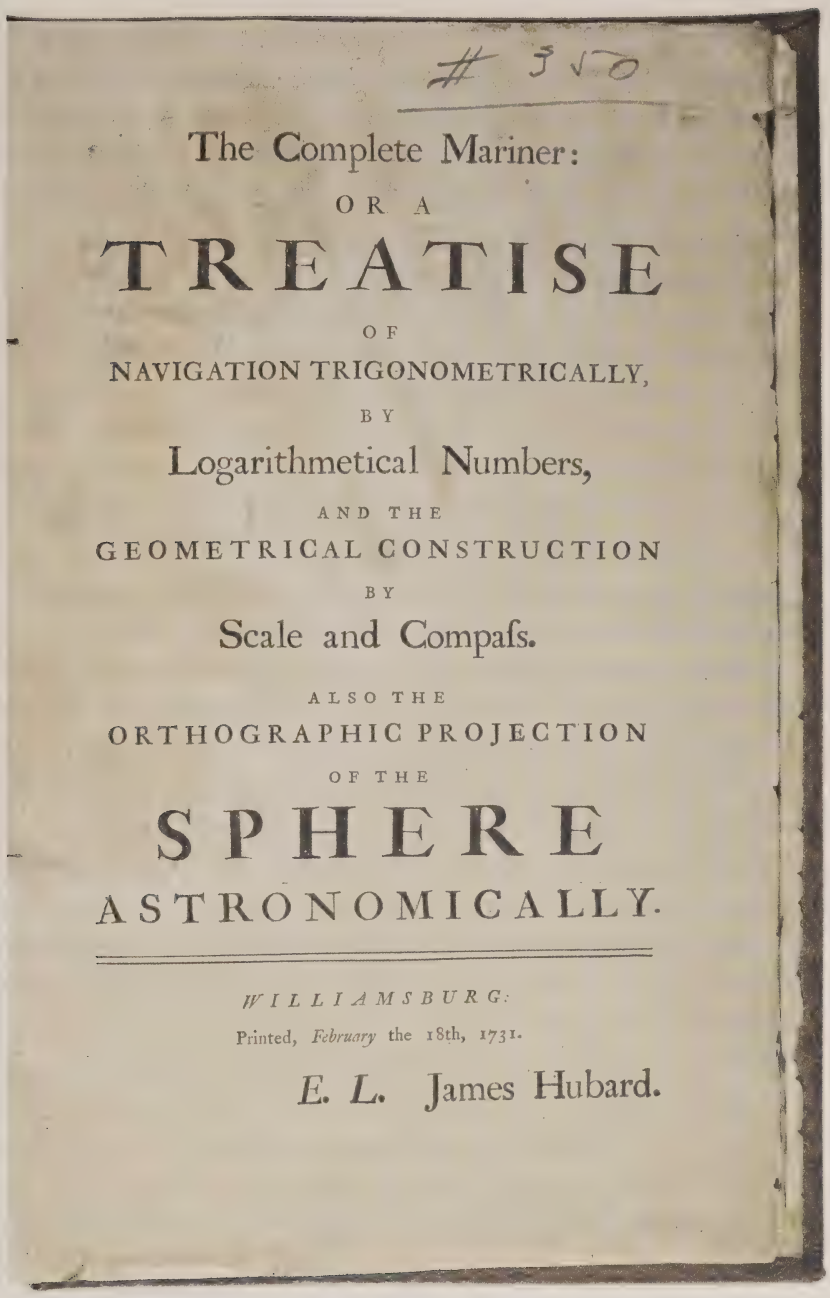
Navigation Aids and Studies in Virginia, Maryland, and Pennsylvania

EXCEPT FOR the Herrman map, *Virginia and Maryland*, published in 1673, no navigational aids in the form of books or charts seem to have proceeded from the colonies south of Long Island Sound in the seventeenth century. In the first half of the eighteenth century, however, there are to be observed in that section varied indications of interest in the art of navigation.

There is found in the possession of the Research Department of Colonial Williamsburg a book comprising fifty-six pages with a printed title page, a partially printed first page and pages 4–56 in manuscript which must be given consideration in this discussion. The title page reads as follows: "The Complete Mariner: or a Treatise of Navigation Trigonometrically, by Logarithmetical Numbers, and the Geometrical Construction by Scale and Compass. Also the Orthographic Projection of the Sphere Astronomically. Williamsburg: Printed, February the 18th, 1731. E. L. James Hubard."

It is not proposed to discuss at length this curiously interesting book. It raises so many questions as to authorship and purpose that it should become the subject of a special study. One naturally thinks of the statement beneath the imprint, "E. L. James Hubard," as meaning "Ex Libris James Hubard," a mere indication of ownership. It may be, however, that there was a relationship of a James Hubard with the actual composition of the book. That is one of the questions that awaits an answer.[39] It is probable

39. This book was first brought to my attention several years ago by Miss Bertha Frick of the Columbia University Library, who came upon it in the course



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The Complete Mariner:

OR A

TREATISE

OF

NAVIGATION TRIGONOMETRICALLY,

BY

Logarithmetical Numbers,

AND THE

GEOMETRICAL CONSTRUCTION

BY

Scale and Compaſs.

ALSO THE

ORTHOGRAPHIC PROJECTION

OF THE

SPHERE

ASTRONOMICALLY.

WILLIAMSBURG:

Printed, *February* the 18th, 1731.

E. L. James Hubard.

The Complete Mariner of Williamsburg, 1731, is a treatise on practical navigation. It is a work of folio size with title-page handsomely printed and text in manuscript. *Colonial Williamsburg.*

that in this work we have one of those manuscript textbooks which played a part of importance in the educational system of colonial America.[40] Productions of this sort, however, were not usually provided by authors or copyists with printed title pages. William Parks, the printer, went to Williamsburg in the summer of 1730. One of his early jobs outside the government work must have been the setting of the *Complete Mariner* title page. It would be interesting to know the purpose behind its printing. But whatever that purpose may have been, the existence of the book suggests that in 1731 in the place of its origin there was a living interest in the subject of navigation.

The offer in 1714 by the Parliamentary Commission on the Longitude of a reward of £20,000 to anyone who should devise a practicable method of determining accurately longitude at sea echoed throughout the world. It is not a matter for surprise that it was heard on the American shores. In the *Maryland Gazette* for May 27, 1729, one John Smith, of Cecil County, Maryland, addressed the community at large in a letter in which he intimated, as Sebastian Cabot had done two centuries earlier, that God had revealed to him a method for determining longitude at sea. With what seems unusual simplicity or a remarkable degree of trustfulness in his fellow man, Mr. Smith offered to share this precious knowledge provided the person made the recipient of the secret would not forestall him in the matter of the Parliamentary reward. The whole incident is without point except that it has about it a pleasing screwiness—no other word seems appropriate—and that it indicates the world-wide interest then existing in the ancient problem of determining longitude at sea.

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of her compilation of a bibliography of *Virginia* imprints. Recently Mr. Arthur Pierce Middleton, whose study of the maritime history of the Chesapeake is soon to be published by the Institute of Early American History and Culture, Williamsburg, sent me a full and interesting memorandum on the book.

40. On this subject see *Papers of the Bibliographical Society of America*, XXXII (1938), 17–37: James Mulhern, "Manuscript School-Books."

While Mr. Smith was pondering the problem of longitude in Cecil County, Maryland, a more practical sort of man was at work on navigation matters a few miles away in Philadelphia. This survey of contributions to navigation has concerned itself so far with books of sailing directions, charts, and manuals of practice. Nothing has yet been said of instruments of navigation. American inventiveness was now to have its part in the development of these aids to the mariner. The story next to be related has to do with one of those curious incidents in the history of science and mechanics in which two men without collusion arrive at identically the same results at almost the same time. It seems to have been about the year 1730 that Thomas Godfrey, the Philadelphia glazier and natural mathematician, brought to a virtual conclusion his construction of an instrument of observation upon the principle which in 1734 appeared before the world embodied in the Hadley quadrant, the implement which very slowly supplanted upon the ships of the world the celebrated Davis quadrant continuously in use for something like two centuries. The claim to priority was asserted by Godfrey as early as 1734, and support of his claim was given promptly and effectually by James Logan, of Pennsylvania.[41] The Royal Society recognized his deserts to the extent of giving him a reward in the form of household furniture to the value of £200. In his representations to the Royal Society, Logan affirmed his belief that the Godfrey quadrant had been actually used at sea six months before Hadley's had been described. Certainly the fact that Godfrey made such an invention seems never to have been doubted. There is an unprejudiced statement in a work by an English writer published in London about 1740, entitled *The Description, Use, and Excellency of a New Instrument, or Sea Quadrant, Invented by Caleb Smith.*[42]

41. Carl and Jessica Bridenbaugh, *Rebels and Gentlemen* (New York, 1942), 307–308.

42. It is incidental to our main interest to observe that Caleb Smith's sea-quadrant was a modification of the Hadley quadrant in that it was equipped with a telescope. It is illustrated in a folding plate accompanying the book cited in the

The author of this work, presumably Smith himself, writes as follows on the subject of the quadrant of the kind invented by Godfrey and Hadley, which he believed had been supplanted already by his own improvement: "Those who first surmounted this Difficulty, were Mr. Hadley in London, and Mr. Godfrey in Pensilvania ... it is somewhat surprising, that both these Gentlemen, tho' at a great Distance, had the good Fortune, unknown to each other, to hit upon this useful Invention, about one and the same time; for it appear'd upon a careful Examination before the Royal Society, that Mr. Logan, Chief-justice of the Province of Pensilvania, had transmitted an accurate Description of Mr. Godfrey's Instrument to England, before Mr. Hadley's was publish'd in the *Philosophical Transactions*; and accordingly a Minute is made of this Affair in the Royal Society's Books. The original Proofs, or Affidavits that were made, in Mr. Godfrey's Favour, remain in the Hands of Mr. Peter Collinson, F.R.S."

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text. Mr. George L. Miner of Providence has deposited temporarily in the John Carter Brown Library a quadrant of the sort illustrated in the Caleb Smith book. Upon its arc is stamped the statement: "Made by Benjamin King in Newport for [*blank space for owner's name*]."

CHAPTER 6

Two Notable Charts of the Chesapeake

ALONG THE SHORES of the Chesapeake and upon the rivers and creeks which flowed into it lay the tobacco plantations of Virginia and Maryland. At the head of the Bay and at other places in the tidewater area were iron manufactories which began, in the first half of the eighteenth century, to be of considerable potential importance in the English economy. Staves and timber from the local forests had also become in that period an important exportation of the Chesapeake colonies, and all these—tobacco, iron, and wood products—were bulky commodities requiring many bottoms for their shipment. As the middle years of the century approached, the Chesapeake became one of the busiest waterways of the country. Within it were to be found the ships of England, New England, and the West Indies. It is not a matter for surprise, therefore, that there was created in 1735 a large chart of the Bay and some of its principal rivers for the comfort of the captains who came thither for the iron and timber and for the bulky hogsheads of Sweet Scented and Oronoco. This was the chart entitled, *To the Merchants of London Trading to Virginia and Maryland, This Mapp of the Bay of Chesepeack, with the Rivers Potomack, Potapsco North East, and part of Chester, Is humbly Dedicated & Presented, by Walter Hoxton. 1735*. It is impossible to write on the subject of American contributions to navigation without mentioning this large and detailed chart, even though not everyone may be inclined to accept it as an American work. Walter Hoxton was a shipmaster in the tobacco trade who made twenty-three voyages to Maryland between 1699 and 1735. His brother and his nephew removed from London and settled in Maryland at some time before the publication of the chart, just how long before is not clear.

Because of this long association with it and because of the residence there of his closest relatives he may have regarded that colony rather than London as his home station. Obviously he must have stayed in the country for long periods in order to acquire the close familiarity with its Bay and rivers displayed in the configurations and in the record of soundings engraved upon the chart which bears his name.

The Hoxton chart of the Chesapeake measures thirty-seven by fifty-six inches. Upon its face are engraved detailed sailing directions for special areas. Its most interesting inscription, however, is the extensive one headed "An Attempt towards Assertaining the Limits Course & Strength of the North East Current on the Coast of Virginia." Appended to the description of what we now call the Gulf Stream, Hoxton gave a set of tables showing the limits of the Stream so far as these affected ships bound for the Virginia capes. In a later section it will be pointed out that Hoxton anticipated the work of both Benjamin Franklin and William Gerard De Brahm in the study of the Gulf Stream as a factor in transatlantic navigation.

Two copies of the Hoxton chart are found in the British Museum and one in the Public Record Office. So far as known, the only copy preserved in this country is the well-worn specimen owned by the Maryland Historical Society. In its original form, therefore, it is little known, but its derivatives, as will develop, are familiar to many students of American maritime history.[43]

In the year 1776 the London publishers, Robert Sayer and John

43. Mathews, *The Maps and Map-Makers of Maryland*, 386–388, early called attention to this admirable cartographical production. The indebtedness of the author of this paper to Mr. Arthur Pierce Middleton, gratefully acknowledged in an earlier note, has been increased by a communication received from him on the subject of the Hoxton chart. The present account of it and its derivatives and the data on Walter Hoxton himself have been made available through Mr. Middleton's generous interest. In his own forthcoming work this chart will receive extended treatment. [Arthur Pierce Middleton, *Tobacco Coast, a Maritime History of Chesapeake Bay in the Colonial Era* (Newport News, Va., 1953; reprinted Baltimore, Md.: Johns Hopkins University Press, 1984)].

Bennett, brought out *A New and Accurate Chart of the Bay of Chesapeake ... Drawn from Several Draughts made by the most Experienced Navigators, Chiefly from those of Anthony Smith Pilot of St. Marys ... 1776*, a cartographical production in the grand manner splendidly engraved and printed on four large sheets, measuring, overall, thirty-seven and one-half by fifty-five inches.[44] It seems impossible to say more of Anthony Smith than is conveyed by the designation of him in the title and in another place on the face of the map as a pilot of St. Mary's, the ancient Maryland town which lies close to the point where the Potomac enters the Chesapeake. The question of identifying Anthony Smith becomes one of small consequence, however, when it is realized that the great chart which bears his name is but a revision, without acknowledgment, of the Hoxton chart of forty years earlier. Its additional matter and its revised soundings are of importance, but it remains true that in all its essentials the Anthony Smith chart is the Walter Hoxton chart in a new dress. So few and so superficial in character are the differences between the two charts that the Smith production could well have been engraved from a copy of the older chart annotated by the Pilot of St. Mary's. That dim figure, by the way, may have been completely innocent of the deception practiced by the publishers in distant London.

It was the fortune of this chart, bearing the name of a Maryland pilot, to become, soon after it appeared, one of the chief elements in the second part, published in 1777, of the maritime atlas known as *The North American Pilot*. In that memorable collection it may have become of high usefulness to the British ships and squadrons which entered the Chesapeake at various times throughout the Revolution. But in the year 1778 it was reëngraved in Paris and placed in the *Pilote American Septentrional*, Le Rouge's French

44. Mathews, *The Maps and Map-Makers of Maryland*, 402–403; Phillips, *List of Maps of America* (Washington, D.C., 2 volumes, 1901), 227–228, and *List of Geographical Atlases*. 4 volumes. (Washington, D.C., 1909–1920), 1, Part 2, No. 1209–1211.

version of *The North American Pilot.* In the same year it was copied in reduced size for the express use of the French navy, and in 1780 was published by royal order, with many other American maps, in the *Neptune Americo-Septentrional.* In these forms it may equally well have served the French allies of the American cause. It is within the probabilities, indeed, that it played a part of some importance in the tactics and strategy of Admiral De Grasse when in 1781 his blockading fleet made untenable the position of Cornwallis at Yorktown and aided materially in forcing that general's surrender. In 1794 the Anthony Smith chart was reissued in London with the imprint of Laurie & Whittle.

CHAPTER 7

Later Pennsylvania Contributions

THE GROWTH of Philadelphia as a port made it inevitable that sooner or later the great difficulty of approaching the city by way of Delaware Bay and River should be given consideration by the cartographers and compilers of sailing directions. The sand bars and shallows of Bay and River required that ships be piloted through the channels, and from early times down to the present day the pilot station at Lewes, Delaware, called Pilot Town on the chart now to be described, has been important in the maritime life of the Pennsylvania city. It was doubtless from the intimate knowledge of the Lewes pilots, as well as from his own surveys, that Joshua Fisher constructed his *Chart of Delaware Bay from the Sea-Coast to Reedy-Island* and caused it to be engraved and printed in a few copies at Philadelphia in 1756.[45] The accuracy of Fisher's portrayal of that difficult passage was attested on the face of the chart by twenty-two Delaware Bay pilots and by twenty shipmasters whose business customarily took them to Philadelphia. If one may judge from the frequency of its republication,[46] it remained the standard guide to the Delaware Bay and River passage until the end of the century. It has been said, indeed, that it continued to be the chief guide to those waters until they were charted by the United States Coast Survey in 1846.

The original Philadelphia, 1756, edition of Joshua Fisher's *Chart of Delaware Bay* is known to exist today only in the copy owned by the Maryland Historical Society.[47] One explanation of this

45. Charles Evans, *American Bibliography*, No. 7657.

46. Phillips, *A List of Maps of America*, 1, 262–263, and his *List of Geographical Atlases*, 1, Part 2, Nos. 1207, 1208, and 1209.

47. In 1948, The John Carter Brown Library acquired a copy in London.

SUSSEX COUNTY
Cape Henlopen
Cape Henlopen Hill
Lewes Creek
Lewes Town
Lewes Beach
Cape Henlopen Light
Cape May
Cape May Light
Cape May Channel
CAPE MAY COUNTY

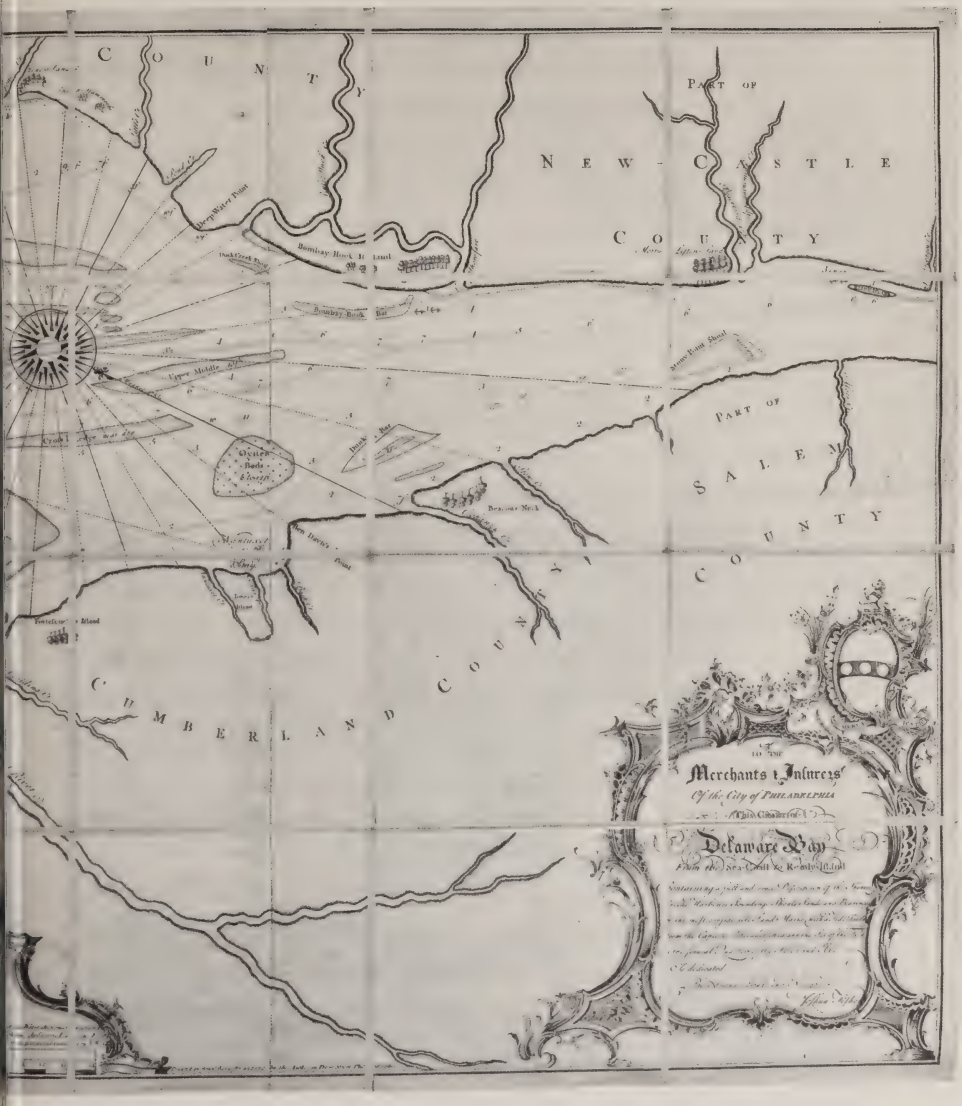
C O U N T Y
PART OF
N E W - C A S T L E
C O U N T Y
PART OF
S A L E M
U N T Y
C O U N T Y
C U M B E R L A N D
To the
Merchants & Insurers
Of the City of PHILADELPHIA
This Chart of
Delaware Bay

CHART OF DELAWARE BAY. The original *Chart of Delaware Bay* by Joshua Fisher, published and suppressed, at Philadelphia in 1756. *John Carter Brown Library.*

extraordinary degree of rarity is to be found in the apprehension felt by the governor and council of Pennsylvania lest the dissemination of such a guide in 1756, in the midst of war, should enable a French fleet to find its way through the sand bars which formed the protection of Philadelphia against invasion by sea. Fisher was ordered, therefore, to postpone the publication of his chart until that danger should be past. In his reply to the governor's communication the map-maker protested that among the threescore pilots regularly cruising off the Delaware capes in the navigation season some would inevitably be found to provide guidance to the invader, or that, if such guidance were not available, an enemy who might have obtained possession of a copy of the chart would be deterred from entering the Bay by its portrayal of the complexity of the channels to be followed. Furthermore, he clearly stated, the intricate passage of the upper river from Reedy Island to Philadelphia had been left uncharted, and for that reason the map as engraved was virtually useless to a stranger. And, finally, in a *nota bene* which may have been disquieting to governor and council, he added that a few copies of the chart had already been printed and delivered to subscribers and that some of these had even been sent to England. He begged that he be allowed to continue with his distribution and thus complete a project upon which, at the solicitation of others, he had expended a deal of time and trouble and a considerable sum of money.[48]

The circumstance that the Fisher chart is known in only one copy in the state in which it was partly published in 1756 suggests that Fisher's protest was not listened to, and that the distribution of the larger part of his edition was prevented by authority.[49] A

48. *Pennsylvania Archives*, First Series, 11 (1853), 592–594. Wroth speculated that the copy the JCB acquired in July 1948 was one of the copies sent to England in 1756. See John Carter Brown Library, *Report to the Corporation of Brown University, July 1, 1949* (Providence, R.I., 1949), 26–29.

49. The dedication and title within the cartouche of the Maryland Historical Society copy read as follows: *To the Merchants & Insurers of the City of Philadelphia this Chart of Delaware Bay from the Sea-Coast to Reedy-Island. Containing a*

second edition of the chart, completely reëngraved, is known to exist in at least three copies. Though this edition is without place of publication, date, or name of engraver, it is not difficult to accept the attribution generally made of it to Philadelphia. Its date could be any time between the removal of the fear of invasion in the closing years of the French and Indian War and the year 1776, when it served as the model for the London reëngraving of the chart of that year. The year 1775 has been suggested for it, and that seems a reasonable assumption. The notable difference between the first edition of 1756 and this second edition of about 1775 is that in the second the channel is carried up the Delaware River from Reedy Island to the Philadelphia docks.[50]

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full and exact Description of the Shores, Creeks' Harbours, Soundings, Shoals, Sands, and Bearings of the most considerable Land-marks; with a Tide-Table from the Capes to Philadelphia, and the Set of the Tide on the several Quarters of the Flood and Ebb. Is dedicated by a Friend to Trade and Navigation Joshua Fisher. The imprint reads: "Engraved by Ja[s] Turner, and Printed by John Davis for, and sold by the Author in Front-Street Philadelphia." Evans No. 7657 enters the chart under virtually this title and imprint, but his entry has always teased investigators because of his failure to locate a copy or to refer to the source of his information.

50. In view of the confusion that exists in connection with the Joshua Fisher map, it seems advisable to set down the recognized editions and issues of it chronologically under places of publication, as follows:

Editions of Philadelphia

(1) Fisher's original, dedicated to the Merchants & Insurers of Philadelphia, published in 1756, without portrayal of upper river channel, and with twenty shipmasters signing testimonial.

Copy: The Maryland Historical Society [and from 1948 The John Carter Brown Library].

(2) Edition dedicated also to the Merchants & Insurers of Philadelphia, with upper river channel portrayed, and with twenty-two shipmasters signing testimonial. This edition, printed from an entirely different plate, is attributed by the Rosenbach Company (No.184 in catalogue, *The Sea*, 1938) to Philadelphia, 1775. This edition was not necessarily printed in Philadelphia, but the attribution of it to that city seems reasonable. Copies: Historical Society of Pennsylvania, with handwritten date "Feb. 28, 1756" in cartouche. The copy described in the Rosenbach catalogue was later sold to the Atwater Kent Museum, Philadelphia. A third copy is in the William L. Clements Library.

There exist in the Historical Society of Pennsylvania two manuscript versions of the Fisher map. One of these, signed by Joshua Fisher, includes the passage of the river only to Reedy Island, while the other carries it all the way to Philadelphia. It has been sensibly concluded that the first of these is the original draft of the Fisher map of 1756, while the second, with its delineation of the river passage to Philadelphia, provided the copy for the second Philadelphia edition mentioned above under the attributed date 1775. This feature was incorporated in the London reëngraving of 1776 found in Faden's *North American Atlas* and in the second part of Sayer & Bennett's *North American Pilot*, published in 1777. There seems to exist no record of sailing directions having been is-

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Editions of London

(3) Faden, London, March 12, 1776. (Phillips, *A List of Maps of America*, 1, 262. Copies in Library of Congress and other libraries.)

(4) Sayer & Bennett, London, July 10, 1776. (Phillips, *A List of Geographical Atlases*, No. 1209. Copies in many libraries.)

(5) Andrew Dury, London, November 30, 1776. (Phillips, *A List of Maps of America*, 1. 262. Copy in Library of Congress.)

(6) Laurie & Whittle, London, May 12, 1794. (*Ibid.* 1. 263. Copies in Library of Congress and other libraries.)

Editions of Paris

(7) Le Rouge, 1777. (*Ibid.* 1. 262. Copies in many libraries.)

(8) *Neptune Americo-Septentrional*, 1778. (Phillips, *A List of Geographical Atlases*, No. 1211.)

For a very brief comment upon the Fisher chart, see Marion V. Brewington, "Maritime Philadelphia, 1609–1837" in *The Pennsylvania Magazine of History and Biography*, LXIII (April, 1939), where opposite page 93 is a reproduction of the chart from the Historical Society copy entered in this note as No. 2. A more extended, unsigned note in the same magazine, LIX (April, 1935), 181–182, asks for information concerning the editions of the Fisher chart. At that time the presence of a copy of the first edition of the chart in the Maryland Historical Society was not widely known. The author is grateful for a letter from Mr. Edwin Wolf, II, of Philadelphia, discussing the editions of the Fisher chart, and to Mr. Roland Tree of London and Mr. J. Clements Wheat of Bay City, Michigan, for knowledge of the location of the 1756 edition of the chart. He is under obligation, also, to Mr. James W. Foster, of the Maryland Historical Society, for two photographs of the map, and for permission to reproduce it.

sued to accompany the original Philadelphia edition of the Fisher chart, but in 1776, the year the chart was reëngraved in London, there was published separately in that city by "W. Faden (Successor to the late Mr. T. Jefferys)" a printed guide entitled *Directions for Navigating up Delaware-Bay, from the Capes to Reedy-Island*, "by Capt. James Campbell, Late Commander in His Majesty's Navy."[51] The association seems clear between this guide, issued by Faden in 1776, and the Joshua Fisher *Chart of Delaware Bay* in one of its several editions.

In the Library Company of Philadelphia there is found the single known copy of a broadside, clearly of Philadelphia publication, entitled *Directions to Sail into and up Delaware Bay*. This summary guide to a difficult passage is undated, but a note written in longhand in its lower margin attributes it to the year 1778, and under that year it has been entered in Evans's *American Bibliography*. Upon first learning of the existence of the broadside and of its allocation to this date, one's natural inclination is to suspect that it was merely a copy of Captain Campbell's *Directions* of London, 1776, but a comparison of the two shows that this was not the case and that the Philadelphia broadside is an independent production, a set of directions of local publication which may be thought of as also of local authorship.[52] If the date of issue of the broadside was between September, 1777, and June, 1778, it may have been a publication of the British forces then occupying the city.

The business of publishing sailing directions was not entirely new in Philadelphia when the broadside *Directions* was printed about 1778. In 1774 William and Thomas Bradford, printers, brought out an anonymous publication, *Directions for the Gulph*

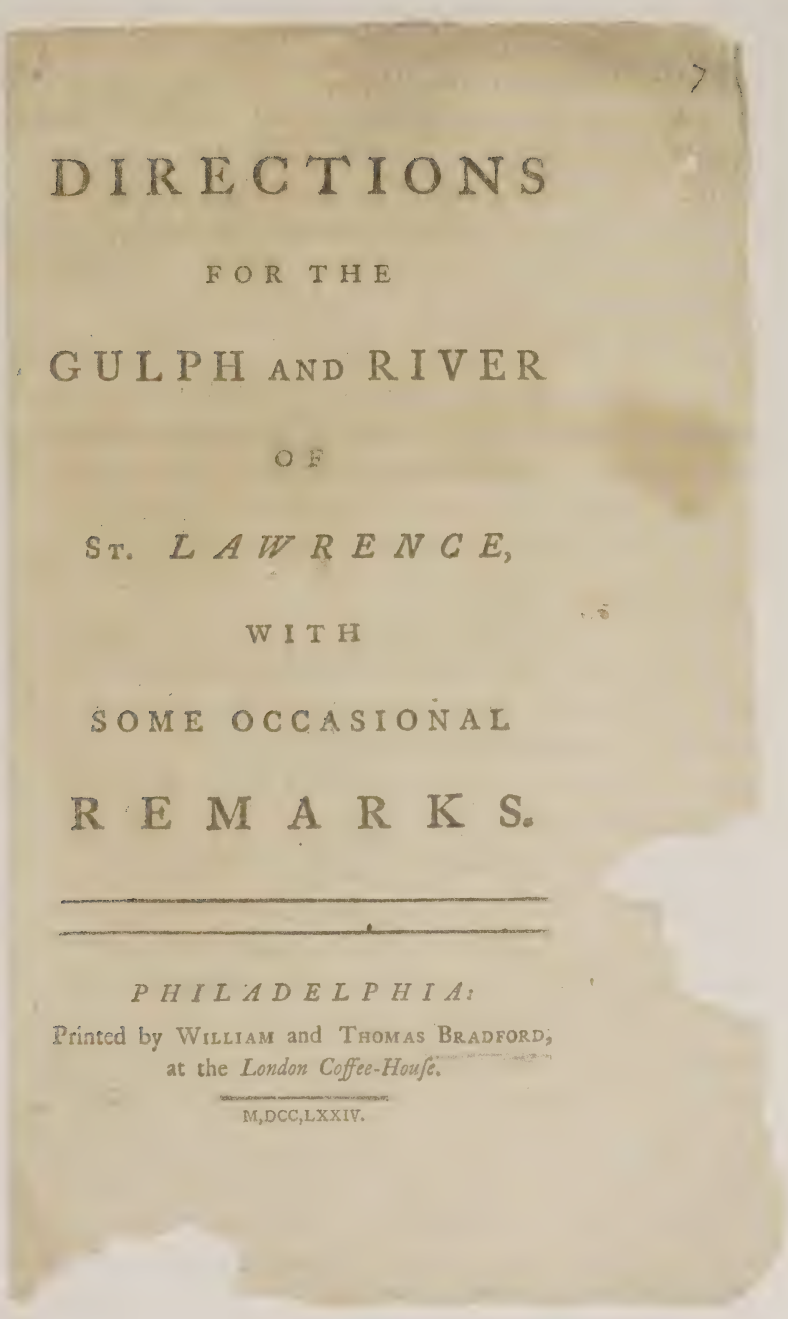
51. Copy in the John Carter Brown Library. See also description of another copy in note to Item 185 in *The Sea*, catalogue issued by the Rosenbach Company, 1938. A third copy is in the Library of Congress.

52. Evans, No. 15784. A photostat copy of this broadside has been sent me by Mr. John H. Powell of the Free Library of Philadelphia, with which institution the Library Company of Philadelphia, Franklin's ancient foundation, is now incorporated.

and River of St. Lawrence.[53] Because of likeness of purpose and title one might suppose that this pilot was the basis of the "Sailing Directions for the Gulf of St. Lawrence," which appeared a year later in London as one of the elements in *Sailing Directions for the North-American Pilot*.[54] Comparison shows, however, a complete absence of similarity between the texts of the two works, nor does there seem to be any likeness between the Philadelphia directions and those in contemporary editions of *The English Pilot: The Fourth Book*. In the absence of contradictory evidence, therefore, it seems permissible to describe the *Directions for the Gulph and River of St. Lawrence*, of Philadelphia, 1774, as an American contribution and one of the earliest sets of sailing directions to be separately printed in what is now the United States.

53. Copy in the John Carter Brown Library.

54. This work was brought out in 1775 to accompany Part 1 of the Thomas Jefferys, *North American Pilot*, published by Sayer and Bennett in London in 1775. The "Sailing Directions to the above Charts" are advertised on the title page of the *Pilot* as available. The important part played by Captain James Cook in the surveys upon which the charts of the Canadian waters were based is summed up in William Wood, ed., *The Logs of the Conquest of Canada*. (Toronto: Champlain Society, 1909), xix–xxvi.



DIRECTIONS

FOR THE

GULPH AND RIVER

OF

ST. *LAWRENCE,*

WITH

SOME OCCASIONAL

REMARKS.

PHILADELPHIA:

Printed by WILLIAM and THOMAS BRADFORD,
at the *London Coffee-House.*

M,DCC,LXXIV.

Directions for the Gulph and River of St. Lawrence. Published in Philadelphia during 1774, this is one of the earliest printed publications of sailing directions to be made in what is now the United States. *John Carter Brown Library.*

CHAPTER 8

The Charts of Abel Buell and Bernard Romans

ABOUT the year 1770 the inhabitants of the Connecticut River towns determined that the navigation through and about the sands of Saybrook Bar, lying athwart the entrance to their waterway, should be rendered safer and easier. One of the means proposed to this end was the publication of a hydrographical survey which Captain Abner Parker, of Saybrook, had recently made of the area. In response to their petition of October, 1770, the Connecticut General Assembly gave them permission some two years later to raise by public lottery the money needed to carry their plans into effect. Captain Parker's chart, with the sand bars indicated and with courses and soundings laid down upon it, was engraved by Abel Buell, then of New Haven, and published in that town late in 1773 or early in 1774, though it is true that its dedication to the Governor and Company of Connecticut bore the date 1771. *Cap^t Parker^s Chart of Saybrook Barr* is a large engraving on two copperplates, measuring, when put together, twenty-six and three-quarters by thirty-nine and three-eighths inches. It has been regarded with interest by the bibliographers and local historians of the past generation or so, but in that period no copy has been seen or reported except the specimen preserved in the Connecticut Historical Society. This aid to navigation seems to have filled the need for which it was designed. In a memorial of 1788 Captain Parker reminded the assembly that some years before he had composed a chart which he humbly conceived had been and would continue to be of great service to those whose business took them into the Connecticut River.[55]

55. Lawrence C. Wroth, *Abel Buell of Connecticut* (New Haven, Conn.: The Acorn Club, 1926), 50–55, where is shown a greatly reduced facsimile of the

One of the picturesque figures of the late colonial and early Revolutionary periods in the colonies was Bernard Romans, the Dutch engineer who was sent to this country as an official of the British government about 1757, who became an officer in the American Army in the Revolution, and who died, it is believed, at sea in 1784 while returning from captivity in Jamaica. It is appropriate that the charts and sailing directions he created should be discussed with the work of Abel Buell because there was a close connection between the two men, and it has even been asserted, though never proven, that Buell helped Romans with the coastal surveys embodied in the Florida charts now to be described. It is much more likely that he was employed by Romans not to make soundings and surveys but to help with the engraving of those charts.

Romans was a cartographer of merit whose maps of American colonies and areas are desired by collectors but only rarely acquired by them. His rarest and most conspicuous cartographical production was a map, or rather two maps of nine and four sheets, respectively, published in New York in 1775.[56] These are without descriptive titles, and it was at first planned to issue them as three separate charts, described as follows in Romans's *Proposals*,[57] dated Philadelphia, August 5, 1773: "I. ... the Mississippi from the Natchez down to the Mouth, and from thence East to the Atlantic.... II. The middle Part of EastFlorida, and the Grand Bahama Bank.... III. The South Point of Florida, the Keys...." When the maps were finally published, Numbers II and III were combined to

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original chart. A tracing of the chart was printed in 1885 in the *Public Records of the Colony of Connecticut*, XIII, 503.

56. A full discussion of these charts is in Phillips, *Notes on the Life and Works of Bernard Romans* (Deland, Fla., 1924).

57. *Philadelphia, August 5, 1773. Proposals for Printing by Subscription Three Very Elegant and Large Maps of the Navigation, to, and in, the New Ceded Countries* (Philadelphia, Pa., 1773). The only recorded copy of this revealing broadside was presented to the John Carter Brown Library in 1941 by Dr. A. S. W. Rosenbach.

PHILADELPHIA, AUGUST 5, 1773.

PROPOSALS

FOR PRINTING BY SUBSCRIPTION,

THREE Very Elegant and Large MAPS of the Navigation, to, and in, the

NEW CEDED COUNTRIES.

I. ONE to contain the *Miſſiſippi* from the *Natchez* down to the Mouth, and from thence Eaſt to the *Atlantic*, including all *Weſt-Florida* and the North Part of *Eaſt-Florida*, taking in from the 81ſt to the 93d°: of Weſt Longitude, from *London*, and the 30th and 31ſt°: of North Latitude.

II. The middle Part of *Eaſt-Florida*, and the *Grand Bahama Bank*, to contain the 76°: to the 85°: of Weſt Longitude, and the North Latitude from 26°: to 29°: inclusive.

III. The South Point of *Florida*, the Keys, the Navigation inſide the *Martyrs*, and over the *Bahama Bank*, the Gulph Stream, and North Side of *Cuba*, between 23°: and 26°: North Latitude, and from 76°: to 84°: Weſt Longitude, wherein that dangerous Navigation is more openly, plainly, and accurately laid down than in any Map heretofore attempted by any of the wretched Map-Makers, that have ventured to explain this intricate Part of the *Britiſh* Navigation, ſo neceſſary for every Mariner to be acquainted with.

IV. A Book containing very plain and eaſy Directions to Navigators to that Part of the World, and a conciſe natural Hiſtory of the ſaid Countries, from the Author's own Obſervations.

By BERNARD ROMANS, *Late Principal of the Deputy-Surveyors for the Southern Diſtrict of* AMERICA, *and firſt Commander of the Veſſels on the Service of that Office.*

CONDITIONS.

I. The Work ſhall be immediately engraven and printed, as ſoon as 150 Subſcribers ſhall have favoured the Author with their Names.

II. The ſaid Work ſhall be embelliſhed with emblematical Title Prints, and ſome other ornamental Pieces, carefully engraven by a maſterly Hand, under the Author's own Inſpection, and ſtruck off on the beſt Paper poſſible for ſuch a Work; the Book to be in large Octavo, and as neatly printed as poſſible; in which will alſo be ſundry neceſſary Plates. For Maſters of Veſſels, who either do not chuſe or cannot well afford to have it in ſo elegant a Form, the Direction alone without the Natural Hiſtory, and the Maps on a more common Paper, in order to make it become as univerſally uſeful as ſo neceſſary a Work requires. The Subſcribers Names ſhall be printed in it.

III. Not one Copy ſhall be delivered, or ſold, but to Subſcribers, and that as ſoon as the Sheets and Numbers come out of the Preſs.

IV. Any Perſon that ſhall ſubſcribe for ſix Setts, ſhall have a Seventh gratis.

V. The Price to Subſcribers is Twelve Dollars, for the compleat Copies on fine Paper, and Nine for the common Sort, One Fourth of the ſaid Money to be paid on ſubſcribing, and the Remainder on the Delivery of the ſaid Work; and in Caſe it ſhall not be delivered by the Firſt of *January*, in the Year 1775, the Author obliges himſelf to refund the ſaid Fourth Part, but he hopes to deliver it, at leaſt Six Months ſooner, a maſterly Engraver is now employed on the Work at *New-York*, and in ſix Weeks, from this Date, it is hoped a Sheet ſhall be public. The above Fourth Part would not have been aſked, had not the Author preſumed on the Works being actually begun, and that a large Fund is neceſſary to compleat it.

VI. The Scale on which it is projected, ſhall be no leſs than eight Statute Miles to one Inch.

As this is the firſt Attempt of the Kind, towards ſo extenſive and accurate a Work, and of ſo intricate a Nature, that has yet been made in *America*, and as it is a univerſally wanted and neceſſary Work, for the compleatly executing of which, the Author has been employed with a vaſt Fatigue and Expence ſince the Month of *Auguſt*, 1766, until the 18th Day of *January*, 1773, he hopes that it may meet with the Encouragement he flatters himſelf it deſerves, eſpecially as it will be yet farther ſo coſtly to him, the Payment to the Engraver being £. 3 14 *ſ.* for every 48 Hours he works thereon, as the Author will ſhew by the written Agreement made between him and the ſaid Engraver, if any Gentleman has the Curioſity to ſee it.

The Marine Society at *New-York* have ſeen a Part of the Work ſo long ago as 1770, when it was in a very incomplete State, and notwithſtanding this, they then honoured him with a very kind encouraging Letter, at a Time when he was on the Point of giving up the Purſuit, to which Letter theſe Labours will owe their Exiſtence in Public. The Author returns his Thanks for the kind Encouragement he met with from that truly reſpectable Body of Gentlemen, and more particularly for the late Pains they have taken to forward its Publication, and the generous Preſent they have made him. He alſo begs Leave to obſerve, that his Abilities for ſuch an Undertaking have in the South Part of *North-America*, always been looked upon in a very favourable Light, and they have frequently recommended him to the Notice of the principal Perſons whoſe Buſineſs it was to have ſuch Work done for the Public, in which Capacity he has always given Satisfaction, and by Means of thoſe Employments he has been greatly enabled to carry his own Scheme into Execution, though he cannot thank any but Governor CHESTER for ſuch Employ, all the others having groſly broke their Promiſes to him, by which Diſappointments this Work had almoſt been ſtifled in its Birth; but Perſeverance has at laſt enabled him to compleat it thus far, and he hopes the generous Public will enable him to produce it in a perfect and very elegant Form.

Subſcriptions are taken in by Meſſrs. WILLIAM and THOMAS BRADFORD, CLEMENT BIDDLE, MATTHEW CLARKSON, and NICHOLAS BROOKS, in *Philadelphia*; Meſſrs. RIVINGTON, GAINE, NOEL and HAZARD, MALCOLM, GERARDUS DUYCKINCK, the SECRETARY OF THE MARINE SOCIETY, and Mr. SAMUEL LOUDON, in *New-York*; Mr. JAMES SHAW, at *Suſſex Court-Houſe, New-Jerſey*; and by the Author himſelf, during his Stay in this City. The Curious may at any Time ſee the Originals, and a Specimen of the Engraver's Abilities, by applying to Meſſrs. WILLIAM and THOMAS BRADFORD.

form a single great chart of nine sheets. Number I, in four sheets, was a separate map of a different shape. At least three of the plates employed for these large charts of the Florida waters were engraved for Romans by Paul Revere. The Florida charts were based upon soundings made by Romans and his associates in the course of several years of activity. The thirteen sheets when put together in correct position compose two charts of the difficult Atlantic and Gulf coasts of East and West Florida, measuring approximately, according to Romans's biographer, two by seven and one-quarter and five by five and one-half feet, the most ambitious American production of this sort up to the time of its publication.[58]

But the service to mariners of the Dutch engineer was not confined to the making and publication of the Florida charts. In the same year that these appeared James Rivington of New York published Romans's *A Concise Natural History of East and West Florida.*[59] The appendix to this work comprises, in addition to six pages of other matter, eighty-nine pages of detailed sailing directions for the area represented on the charts, compiled, for the greater part, Romans claimed, from his own observations. Accompanying these directions were three small but clearly engraved special charts: Pensacola Bar, Entrances of Tampa Bay, and Mobile Bar.

There can be no doubt that Romans intended his *Concise History* and the Florida charts to be sold together, though his *Proposals* show that he was willing enough to sell them separately, and

58. Complete copies of the two charts are in the Library of Congress, two sections are in the William L. Clements Library, and a manuscript of the second portion as given in Romans's *Proposals*, cited in the text, is in the library of Mr. Thomas W. Streeter, of Morristown, New Jersey, a Corresponding Member of the Massachusetts Historical Society.

59. The book is fully described and its contents discussed in Phillips, *Notes on the Life and Works of Bernard Romans.*

IMAGE OPPOSITE: *Proposals* by Bernard Romans for the publication of his charts of the Florida coasts, finally brought out in New York in 1775. *John Carter Brown Library.*

even that he would detach the sailing directions from the book and sell that section with copies of the charts printed on cheaper paper. His biographer, P. Lee Phillips, seems to suggest, indeed, that the maps are called for as part of the *Concise History* by the phrase on its title page which reads: "Illustrated with ... Two whole Sheet Maps." This does not seem a reasonable interpretation. The great charts of the Florida waters comprised, as has been said, thirteen whole sheets. These would hardly have been described by their maker as forming "Two whole Sheet Maps."

CHAPTER 9

American Study of the Gulf Stream

IF ONE THING in this world is certain it is that Benjamin Franklin was not the discoverer of the Gulf Stream, and yet many people who should know better continue to accord him that distinction. Franklin's interest in the Gulf Stream or Florida Current seems to have begun about the year 1770. Who it was that first observed the existence of the current as a phenomenon of nature is uncertain, but it is clear enough that its effect upon navigation was taken into account and its position laid down as early as 1685, nearly a century before Franklin caused a representation of its extent and direction to be engraved upon an existing chart of the Atlantic.[60] In the course of that century others made serious studies of the stream and its importance in navigation.

Franklin's interest in the Gulf Stream came about through its interference with the Falmouth–New York transoceanic passage, but it is a fact that long before 1770 the tobacco ships plying between England and the Chesapeake found frequently that they had been "driven to the Northward of the Capes contrary to Expectation." The quoted words form part of an extensive text engraved upon the great chart of the Chesapeake, discussed in an earlier section, which Captain Walter Hoxton brought out in 1735. Captain Hoxton attributed such mischances to the strength of "the North East Current on the Coast of Virginia" and suggested a procedure for their avoidance. The eastward extension of his map was not great enough to admit a graphic representation of the Gulf Stream, but he gave the coordinates by which its breadth and direction might be determined, and recommended that mariners

60. Ralph H. Brown, "The De Brahm Charts of the Atlantic Ocean, 1772–1776," *Geographical Review*, XXVIII (January, 1938), 124–132.

plot them upon their general charts. The data presented in the tables he provided had been gathered by Captain Hoxton himself in the course of his twenty-three voyages to Maryland. These tables and their explanation were copied upon the Anthony Smith map of 1776,[61] where they received a greater degree of attention, but by that time the Gulf Stream had become one of the concerns of two celebrated American observers—Benjamin Franklin and William Gerard De Brahm. A pioneer and a participant for nearly half a century in Southern settlement, surveying, and exploration, De Brahm published in 1772 *The Atlantic Pilot*,[62] a work of text and charts in which he embodied studies of the Florida Stream, that is, the Gulf Stream, which had been made in the course of his passage to England the year before. His studies, indeed, were carried further than his published work indicates, for one of two unpublished De Brahm manuscripts now in the Harvard College Library is a continuation of the printed *Atlantic Pilot*, an extensive addition, with two manuscript charts, to his earlier investigation of the course and rate of flow of the Gulf Stream.[63] It is upon De Brahm's printed work and its charts and upon this manuscript continuation that one may rest his belief in the royal surveyor's right to be mentioned with Franklin in any discussion of the history

61. For discussion of the Hoxton and Smith charts here referred to, see chapter VI, above, of the present study.

62. *The Atlantic Pilot*, "London: Printed for the Author ... MDCCLXXII," 3 charts and folded table. The dedication is signed "William Gerard de Brahm." Sabin No. 7324 gives the title incorrectly. A French version, with an extensive note on the Gulf Stream added by the translator, was published sometime after 1793 as *Recherches faites par ordre de sa Majesté Britannique ... pour rectifier les cartes & perfectionner la navigation du Canal de Bahama*. Sabin, No. 7326, enters an edition with the impossible date [1771], and another of Paris, 1788. He gives the name of the translator as Charles Romme.

63. Ralph H. Brown, "The De Brahm Charts of the Atlantic Ocean, 1772–1776," *Geographical Review*, XXVIII No. 1 (January, 1938), 124–132. [For a more recent study, see Louis de Vorsey, "Pioneer Charting of the Gulf Stream: The Contributions of Benjamin Franklin and William Gerard de Brahm," *Imago Mundi*, vol. 28 (1976), pp. 105–120.]

of scientific interest in the Gulf Stream. It seems certain that De Brahm did a great deal more work on the problem than Franklin thought of giving to it. In the *Transactions of the American Philosophical Society* for 1786, however, occurs a communication which shows clearly that in oceanography, as in everything he engaged in, Franklin played an important part. His "Letter ... to Mr. Alphonsus le Roy ... Containing Sundry Maritime Observations" is essentially Franklinesque, its words and tenor revealing the reflective, practical philosopher at work. In 1769 or 1770, when he was still concerned in the management of the British Post Office in the colonies, he had been asked to look into the complaint that the supposedly fast mail packets from Falmouth to New York were slower in their passages by a fortnight than the American merchant vessels from London to Rhode Island. For an explanation of this unaccountable circumstance Franklin consulted a Nantucket sea captain, Captain Folger, who said that it was the opposing current of the Gulf Stream which slowed the packets and that the Rhode Island masters knew the location of the Stream and its phenomena from their whaling experience in the North Atlantic, and, further, that to defeat its effect upon their rate of progress they customarily sailed along its edge or crossed it, whereas the English captains ignored its existence and persistently sailed against its current. Whereupon Franklin had the known data on the course of the Gulf Stream engraved upon the commonly used chart of the Atlantic and tried without success to persuade the English packet captains to take advantage of the added information. No specimen of a chart so amended is known. A copy of it was made in France at some time before 1785, and copies were made in America in 1786 and 1789. One of these, *A Chart of the Gulf Stream*, engraved by James Poupard, of Philadelphia, in 1786, accompanies Franklin's letter to Le Roy, from which we have told the story.[64]

64. *Transactions of the American Philosophical Society*, II (Philadelphia, 1786), 294–329. The chart accompanying this article was also published in the *American Museum* (Philadelphia) for March, 1789.

But Franklin went further than this. In later voyages across the Atlantic he made thermometrical observations of the temperature of the Gulf Stream water, and these he appended to his article in the issue of the *Transactions* for 1786, a worthy addition to the study of the sea and of navigation. In a footnote to this journal of observations made on the voyage of 1785, on board the *London Packet*, Captain Truxtun commanding, he explains that the data "was obligingly kept for me by Mr. J. Williams, my fellow-passenger in the *London Packet*, who made all the experiments with great exactness." None can doubt the degree of interest Franklin would have felt if, having lived a few months longer, he might have heard this Jonathan Williams, Jr., his own grandnephew and diplomatic associate, read before the American Philosophical Society on November 19, 1790, his "Memoir ... on the use of the Thermometer in discovering Banks, Soundings, &-C." That paper introduced a system of avoiding danger when in soundings by the recording of water temperatures. It attracted attention at home and abroad. It was issued separately, with chart, in Philadelphia in 1792 as *Memoir on the Use of the Thermometer in Navigation*, a publication in advance of the paper which appeared in 1793 in the *Transactions* of the Society. An interesting reprinting of the matter of the little book and of its chart was the *Memoria sobre el uso del termómetro en la navegacion*, translated from the English by royal order, and brought out at Madrid in 1794 by the widow of the celebrated Spanish printer, Joaquín Ibarra. Five years later, Williams combined his own studies on this subject with those of Franklin, Captain Truxtun, and one or two others, thus creating the book he published in Philadelphia in 1799 called *Thermometrical Navigation ... Tending to Prove, that by Ascertaining the Relative Heat of the Sea-water ... the Passage of a Ship through the Gulph Stream, and from deep Water into Soundings, May be Discovered in Time to Avoid Danger*.[65]

65. *Transactions of the American Philosophical Society*, III (Philadelphia, Pa., 1793), 82–100; Sabin No. 104297 and note; Sabin No. 104300.

MEMORIA

SOBRE EL USO DEL TERMÓMETRO

EN LA NAVEGACION

PRESENTADA

A LA SOCIEDAD FILOSÓFICA AMERICANA

DE FILADELFIA

PARA PROMOVER LOS CONOCIMIENTOS UTILES

POR JONATHAN WILLIAMS

UNO DE SUS SECRETARIOS.

SACADA DEL VOLUMEN TERCERO

DE SUS TRANSACCIONES FILOSÓFICAS.

TRADUCIDA DEL IDIOMA INGLES

DE ORDEN DE S. M.

IMPRESA DE LA MISMA

EN MADRID

EN CASA DE LA VIUDA DE D. JOAQUIN IBARRA.

AÑO DE MDCCLXXXXIV.

Memoria sobre el uso del termómetro. An edition in Spanish of Jonathan Williams, *Memoir on the Use of the Thermometer,* first published at Philadelphia in 1792. *John Carter Brown Library.*

From the foregoing brief consideration of the work on the Gulf Stream carried on by Hoxton, Franklin, De Brahm, Truxtun, and Williams, it can be said with truth that there was already in existence the tradition of American interest in oceanography when in the nineteenth century Matthew Fontaine Maury became the virtual father of that science.

CHAPTER 10

Later Charts and Sailing Directions

THE PRODUCTION of American works relating to maritime science was a casual and sporadic business in the first two centuries of its operation. None the less, as has been seen, certain definite contributions were made to science in that period in the five distinct categories essential to its practice, that is, sailing directions, charts, instruments of observation, scientific manuals, and treatises on seamanship. In the closing decade of the eighteenth century the production of these elements underwent enlargement and, in a sense, organization; the making of charts, the writing of books, and the manufacture of implements became in this country a business of consequence. The most interesting of these productions of the period 1790–1800 was the series of maritime atlases which in that decade proceeded from the engraving establishments of Boston.

The first of this extraordinary group of atlases, it is believed, was that which Matthew Clark advertised in the *Boston Gazette* for February 22, 1790, describing it as "A Complete set of Charts of the Coast of America ... from Cape Breton ... into the Gulph of Mexico." Several months later, on July 5, 1790, the book was advertised in the *Boston Gazette* as "Just Published." Of three known copies of this Matthew Clark atlas none has a title page, and opinion seems to favor the view that it was published with one.[66] The collection contains eighteen separate prints pasted together on

66. Evans No. 21738 seems to record the title and imprint as if from an actual title page, but the Boston Athenaeum, the Library of Congress, and the John Carter Brown Library copies have no title page. See for description, history, and full contents of this admirable production, Phillips, *List of Geographical Atlases,* III, No. 3667.

twos to form nine large charts. All but one bear upon their faces an engraved certificate in which Osgood Carlton, the Boston teacher of mathematics, testifies that the charts had been compared with those of Holland and Des Barres and found correct. Six of the separate map prints were engraved by Joseph Seymour and two by John Norman. In all probability these prolific and skilled craftsmen were responsible for the remainder of the charts in this first sea atlas of American publication. The source of the surveys and original draughts of the charts has not been determined.

Certainly John Norman must have been extremely busy about this time at the engraving of charts. In 1791, the year following the publication of the Clark atlas, appeared *The American Pilot*, published by John Norman at 75 Newbury Street, Boston.[67] This was an atlas of eleven charts which, in the tradition of *The English Pilot,* were accompanied by sailing directions; though in this instance the directions were relatively brief, occupying only a single large folio leaf. As in the case of the Matthew Clark atlas, no comprehensive study of the origins of the charts, that is, the surveys and the original designs which were placed before the engraver, has been made. It is not easy, therefore, to say to what extent these atlases were fresh productions. The Norman atlas, however, contained at least one chart of complete originality, that is *A Chart of Nantucket Shoals Surveyed by Capt Paul Pinkham,* with the date of publication given as February 16, 1791. Engraved upon the face of that chart is a testimonial in which various Nantucket seafaring men affirm their knowledge of its having been made in 1784 by Captain Pinkham's personal surveys. Added to this testimonial is Captain Peleg Coffin's certification that the Pinkham chart was fully approved by pilots and navigators. It is worth observing that this original chart had its complementary passage in the sailing directions, prefixed to the book and credited to Captain Paul Pinkham, entitled "Directions for Nantucket Shoals." Like the Pinkham chart, this set of directions is obviously an original contribution.

67. Evans No. 23637.

The American Pilot came out in at least four issues, 1791, 1792, 1793, and 1794.[68] The service to many aspects of the life around him performed by the versatile engraver, John Norman, was never of greater consequence than when he made this collection of maritime charts for the coasts of America from Newfoundland to the Island of Cayenne, omitting all detail for the extensive area between Georgia and the northern coast of South America. In *A Pilot for the West-Indies* of Boston, 1795 and thereafter, John Norman's relative and associate, William Norman, made good this omission by the publication of a group of eight well-engraved charts relating to that area of sea and land which we call the Spanish Main.[69]

It is to be hoped that someday an ambitious investigator will make a thorough study of the work in Philadelphia and Boston of the Normans, both John and William. That study will determine the relationship of the two men and under what terms of association they carried on, now together, now separately, a large business in engraving and publishing in Boston.

The ship captain whose business led him from port to port along the North American coast carried with him the charts combined with sailing directions found in *The English Pilot: The Fourth Book,* which since 1689 had been coming our every few years in revised editions. After 1777 he would have had also the two parts of Jeffreys's *North American Pilot.* American rivals to these English

68. Wroth and Adams, *American Woodcuts and Engravings, 1670–1800.* No. 49.

69. Knowledge of the title of William Norman's atlas—*A Pilot for the West Indies*—is derived from the copy owned by Mr. Thomas Streeter. That copy has no title page, but pasted upon the outside paper cover is the title, *A Pilot for the West Indies; Including the Coast of America and Part of the Atlantic Ocean*, a list of eight maps, and the imprint "London. Printed by Laurie & Whittle ... 1794 Boston Republished by W. Norman ... 1795 ..." The date 1795 has been assigned to the atlas. The John Carter Brown Library has a William Norman atlas which seems to be of this edition, but it does not have the pasted-on title to make the attribution certain. That library has also a William Norman atlas of eleven maps of Boston, 1803, bearing the pasted-on title *The New Improved West-India Pilot.* [See also David Bosse, "The Boston Map Trade of the Eighteenth Century," in Alex Krieger and David Cobb with Amy Turner, eds., *Mapping Boston* (Cambridge, Mass., 1999), 36–55.]

publications had been brought out, as has been said, in the form of atlases issued by Matthew Clark and the Normans in the period 1790–1795. As none of these atlases contained full and satisfactory sailing directions, it is likely that the careful and intelligent mariner would add to their printed prescriptions his own observations and explicit directions obtained from local pilots along the coasts he frequented. He might even compile in manuscript for his own use a book made up of directions collected in this way and tested personally over a period of years. This would be his personal *routier*, or "rutter," or "pilot," one of the most cherished of his possessions, a book to be used in connection with the printed charts of his *English Pilot* or later, with his *North American Pilot*, providing a fuller and more detailed set of directions than he could find anywhere in published form. That procedure may have been followed by the New England mariner next to be mentioned. In 1796, the enterprising nautical publisher, Edmund March Blunt, of Newburyport, issued a work, *The American Coast Pilot ... from Boston to all the Principal Harbours ... between Passamaquady and the Capes of Virginia,* by Captain Lawrence Furlong.[70] It is not easy to trace to their respective sources all the sets of direction found in this first edition of the Furlong book, but it is perfectly clear that the directions for the dangerous Nantucket waters, for part of Chesapeake Bay, and for certain ports and rivers of Carolina and Florida were taken from John Norman's *American Pilot* of 1791. The section of the Furlong book headed "Bearings and Distances of Nantucket-Shoals, from the Light-House" copies literally and without acknowledgement a similar section in Norman's atlas, there attributed to Captain Paul Pinkham of Nantucket, who, it will be remembered, was the maker of the Norman chart of the Nantucket waters. Norman could not well complain of Furlong's plagiarism, however, because he in his turn had taken many passages in his own directions from *The English Pilot: The Fourth Book.* The truth is

70. Evans No. 30464.

that one does not condemn the writers of sailing directions for plagiarism. From the fourth century B.C., when the *Periplus of Scylax*, covering the whole Mediterranean, was created by combining into a single ordered text the lesser sectional *peripluses* formed during the preceding centuries, a book of sailing directions has been regarded as the common property of the maritime world. The great volume of knowledge of the coast and harbors of the world that exists today has been formed in just the way here indicated, that is, by Norman adding a few new observations to the material found in *The English Pilot*, and Furlong taking over Norman for his own more extensive work. When Furlong's publisher added greatly to the original work in later editions and, beginning with the eighth, disregarded the Captain altogether as the original source, one sees again the ancient process in operation.

It has been suggested, seriously, that no such person as Captain Furlong ever had existence, that the name was a *nom de plume* for Edmund Blunt, and that this enterprising bookseller himself compiled the *American Coast Pilot* from various sources, manuscript as well as printed.[71] That interesting view, however, is not borne out by the facts. The death of Captain Lawrence Furlong in 1806 at the age of seventy-two years is recorded in the *Newburyport Herald* of May 23 of that year. There exist many documentary references to him testifying to a busy existence as a mariner, from the year 1758 onwards. He may, indeed, have been actively at sea as late as 1801. He is known with certainty to have lived at Newburyport in 1790.[72] One mention of his name which is of interest because of its association with his profession is that which appears in a

71. Alfred B. Stanford, "Blunt's Coast Pilot," *Colophon,* Part XIV (1933).

72. I am very much indebted to Mr. Clarence S. Brigham for the following references to sources outlining the life of Captain Furlong: Essex Institute, *Early Coastwise and Foreign Shipping of Salem* (Salem, Mass., 1934) for Furlong's voyages of 1758–1761; Harriet R. Cooke, *The Driver Family* (New York, 1889), 108, for documents of 1764; Stephen W. Phillips, *Ship Registers of the District of Newburyport* (Salem, Mass., 1937), for voyages of 1801, though the Furlong there named may have been a son; United States Bureau of Census, *Heads of*

supplementary list of subscribers to Bernard Roman's *Concise Natural History of East and West Florida* of New York, 1775.[73] "Capt. Lawrence Furlong, Newbury-Port," clearly was in that list because of his interest in the Florida sailing directions earlier described in the account of the Romans contribution.

But if the existence of Captain Furlong may not be doubted, it is still uncertain whether any of the material in the *American Coast Pilot* is the result of the captain's own observations, whether the whole work is a compilation by him from existing sources, or, finally, whether it is a compilation from existing sources by the publisher Edmund Blunt, given professional sponsorship by affixing to it the name of a mariner well known in the American coastal trade. We have traced to previously existing sources several of its important passages. Naturally the remainder of the book becomes an object of critical scrutiny.[74]

Whatever may have been the origin of the Furlong book, there is no question as to the degree of success with which it met, from the beginning, in its busy maritime world. At a later time Furlong's name, as already said, was dropped from the title page, and Blunt's *Coasting Pilot*, as the book was soon to be called, became in successive enlargements a work of authority. Twelve editions of it were issued before Blunt's retirement in 1833. It was taken over eventually from his sons and successors by the United States Coast and Geodetic Survey, and today is sold annually in large numbers of copies for each of several sections of coast as the *United States Coast Pilot,* the official sailing directions used by everyone whose business takes him to American ports.

Families at the First Census of the United States Taken in the Year 1790. Massachusetts (Washington, D.C., 1908), 91; and the *Newburyport Herald,* 3 May 1806, where it is said that the funeral ceremony of Captain Lawrence Furlong would be held in conjunction with St. John's Lodge.

73. This list is found on the verso of the half-title of the appendix.

74. For a discussion of the authorship of Furlong's *American Coast Pilot*, see *Essex Institute Historical Collections,* LXXIX (April 1943); Russell L. Jackson, "Edmund March Blunt," 101.

CHAPTER II

Later Manuals of Seamanship and Navigation Practice

THE American Sailor: A Treatise on Practical Seamanship,[75] by Samuel Buckner, was published at Newport, Rhode Island, without date, but clearly at some time between June 1, 1790, the date of one of its preliminaries, and December of that year when, according to an inscription on its half-title, the John Carter Brown copy was bought at a vendue in Providence. On the first of the limiting dates, June 1, 1790, six Newporters signed a testimonial recommending the treatise as containing excellent instructions for young seamen, and other matter which would doubtless be of service even to the most expert. On that same day Captain James Gramon of Providence, wrote: "I think the performance does honor to the Author."

Acquaintance with the book convinces one that in its day it must have been a valuable work of instruction. Within its ninety-six pages of text are comprised ninety-eight sections, each dealing with a different aspect of the art of ship management, everything from the "Hanging of Ships Rudders" on page 6 to "Recovering drowned Persons" on page 95. The book maintains throughout a sharp distinction between the art of navigation and the art of seamanship, eschewing any attempt to teach the procedures of position-finding and determining courses and distances and latitudes and longitudes, or any of those mathematical matters with which navigation as a science is concerned.

After the build-up of Samuel Buckner's book in the preceding paragraphs, it seems a pity to speak of it in derogatory terms,

75. Evans No. 22377.

but that must be done. Reading casually his forthright pages, one thinks of Samuel Buckner as an honest Yankee sailor who returned from his voyaging, like Ulysses, "full and sage with usage" and sat himself down in Rhode Island to record for the sailors of a newer generation his experience with ships and their handling. When one examines the book critically, however, its seems to be just a little too good, too well written, too full of expertness, too authoritative for so dim a figure to have brought into being, and after a search into the existing literature of seamanship one learns that its text is nothing more than an abstract of an English book of 1777, *A Treatise on Practical Seamanship*, by William Hutchinson, "Mariner, and Dock Master, at Liverpool." According to its imprint, this work was "Printed, and Sold for the Author at all the principal Seaports in Great-Britain and Ireland." There has been so much plagiarism in books of instruction of all sorts, so much unacknowledged transferring of texts from man to man and generation to generation that one who lives with them comes hardened to the lack of conscience displayed by their publishers and authors. In this particular instance, however, one experiences a feeling of disappointment, for there seems something salty and genuine about the Buckner book, and for Rhode Islanders it has always been pleasant to think that work an outgrowth of the maritime life of their state. The Newport and Providence endorsers of the treatise seem above suspicion, and Peter Edes, printer of the book and 'Proprietor of the Copy Right," would hardly have lent himself to chicanery of this character. The villain of the piece, one is forced to conclude, is Samuel Buckner himself; and who he may have been does not appear in any available Rhode Island sources. None the less, if words mean what they say, it seems certain that the man had existence, for Captain James Gramon, his Providence endorser, begins his recommendation of the book with the words, "At the request of Mr. Samuel Buckner, I have read a Manuscript entitled 'A Treatise on Practical Seamanship.'" One regrets moving *The American Sailor* from the list of American contributors to

the art of navigation, but it is just as well to know where we stand in this matter of authorship.[76]

The next work to be considered is of a more satisfactory character. Few American books of the eighteenth century excelled in interest and usefulness the work of Commodore Thomas Truxtun entitled *Remarks, Instructions, and Examples Relating to the Latitude & Longitude; also, the Variation of the Compass,*[77] published at Philadelphia in 1794. Its author was the naval captain who commanded the *Constellation* in her celebrated victories over *L'Insurgente* and *La Vengeance*, the former merchant captain who in 1786 had taken the *Canton* from Philadelphia to the China coast, the first ship to go thither from that city. In addition to his many distinguished services at sea, Truxtun was a competent mathematician, an oceanographer, and a practical naval architect. In his book one finds a complete treatise on position finding, a section devoted specifically to lunar observations, a section on masting of ships, and an account of the general duties of officers on ships of war. All these are practical treatises drawn from a rich experience and illuminated by tables and by many examples fully worked out. Accompanying the handsome folio in which these several matters are set forth is a large folding plate of "A 44 Gun Frigate in the Navy of the U.S. of America Masted according to the annexed System...," drawn by J. Fox and engraved by Thackra, and "A General Chart of the Globe, Shewing the Course of the Gulph Stream, and various

76. JCBL, Wroth Papers. In a letter to Wroth dated 20 February 1950, M. V. Brewington drew Wroth's attention to a notice in the *Maryland Herald* for 10 August 1790 of a forthcoming "compendium of mixed mathematics for the Seaman's use, with great improvements in keeping a sea-journal" to be titled "The American Seaman." For this work, B. M. Ward of Easton, Talbot County, Maryland requested information on the latitudes and longitudes of "every material American sea-port town on the Continent of America." Brewington commented that he thought this book had never been published, "although there's a close similarity in title to Buckner's (and date the same), there is evidently no connection from the content as indicated in the ad."

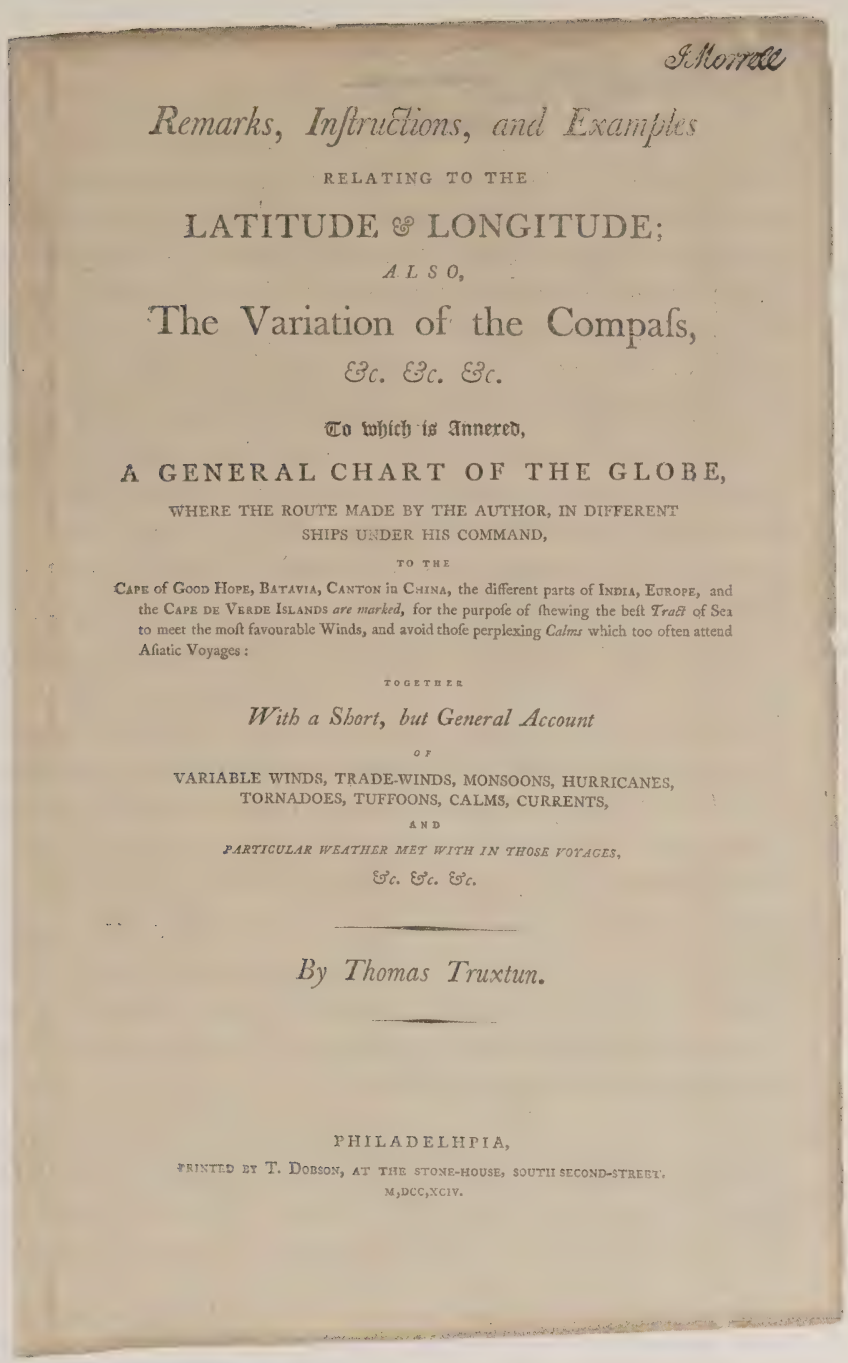
77. Sabin No. 97281; Evans No. 27823.

Tracks to and from the East Indies, China, Europe &c. By Capt^n. Tho^s. Truxtun." All in all, the book is a contribution to the art of navigation, seamanship, shipbuilding, and naval customs reflecting credit upon the merchant and naval establishments of a young country struggling against the odds for a place among the nations. It could not have failed to increase respect for that country among the mariners of the world. Truxtun's later works were, *Instructions, Signals, and Explanations Offered for the U.S. Fleet* (1797), and *A Few Extracts from the Best Authors on Naval Tactics* (1806).[78]

Truxtun's illustration of the Gulf Stream on his chart and his discussion of that phenomenon in his "explanation of the chart" show clearly dependence, especially in the acceptance of the usefulness of temperature recordings, upon "that great philosopher, the late Dr. Franklin." In another of his preliminaries, a letter addressed to the Reverend John Ewing, "President of the University of Pennsylvania," he speaks of the "maze of extravagance" in which one Mr. Churchman had lost himself in his discussion of the variation of the compass. The reference must be to another American work of Philadelphia origin which belongs in this record even though the Commodore and all others of later generations disagree with its findings. This is *An Explanation of the Magnetic Atlas, or Variation Chart* (Philadelphia, 1790), in which John Churchman, cartographer and mathematician, endeavored to prove that "the Variation and Latitude being accurately known, the Longitude is of Consequence truly determined." The book is a brief commentary upon the large map, the "Magnetic Atlas or variation chart," in which John Churchman set forth his theory in graphic form.[79]

78. Article, Thomas Truxtun, in *Dictionary of American Biography.* [For a book-length study, see Eugene S. Ferguson, *Truxtun of the Constellation: The Life of Thomas Truxtun, 1755–1822.* Baltimore, Md., 1956; reprinted Annapolis, Md., 1982.]

79. Evans No. 22406. A fine copy of the Churchman map is in the Houghton Library, Harvard University.



J. Morrell

Remarks, Inſtructions, and Examples

RELATING TO THE

LATITUDE & LONGITUDE;

ALSO,

The Variation of the Compaſs,

&c. &c. &c.

To which is Annexed,

A GENERAL CHART OF THE GLOBE,

WHERE THE ROUTE MADE BY THE AUTHOR, IN DIFFERENT SHIPS UNDER HIS COMMAND,

TO THE

CAPE of GOOD HOPE, BATAVIA, CANTON in CHINA, the different parts of INDIA, EUROPE, and the CAPE DE VERDE ISLANDS *are marked*, for the purpoſe of ſhewing the beſt *Tract* of Sea to meet the moſt favourable Winds, and avoid thoſe perplexing *Calms* which too often attend Aſiatic Voyages:

TOGETHER

With a Short, but General Account

OF

VARIABLE WINDS, TRADE-WINDS, MONSOONS, HURRICANES, TORNADOES, TUFFOONS, CALMS, CURRENTS,

AND

PARTICULAR WEATHER MET WITH IN THOSE VOYAGES,

&c. &c. &c.

By Thomas Truxtun.

PHILADELPHIA,

PRINTED BY T. DOBSON, AT THE STONE-HOUSE, SOUTH SECOND-STREET.

M,DCC,XCIV.

Commodore Truxtun's *Remarks* of Philadelphia, 1794, was a valuable contribution to several aspects of navigation, seamanship, shipbuilding, and naval customs. *John Carter Brown Library.*

The establishment and development through many editions of Furlong's *American Coast Pilot,* described in the preceding section, was not the only service to navigation performed by Edmund Blunt, the Newburyport publisher. In the year 1799 Blunt brought out the first American edition (from the thirteenth English edition) of John Hamilton Moore's *New Practical Navigator,* the original appearance of which had been in the year 1772. Several major errors were corrected in that American edition. A year later, in 1800, he issued a second edition of the work with further corrections. Both revisions had been carried through by Nathaniel Bowditch, the self-taught Salem mathematician and ship captain. Blunt sold seven thousand copies of the amended Moore and, when planning a third edition of the work, he determined to have made a complete revision, not only of the tables but of the various other sections which made up the book. When the work so planned came out in 1802, it followed closely the organization of Moore's work, but in it some eight thousand errors of the tables had been corrected, the astronomical and mathematical chapters had been enlarged, and the rules and prescriptions for the several methods of sailing had been rewritten. All this was the achievement of Nathaniel Bowditch. A close comparison of the two works brings conviction that Blunt's action in giving a new title to the book and placing a new author's name on the title page needs neither apology nor justification. *The New American Practical Navigator* by Nathaniel Bowditch of Newburyport, 1802, is so completely a revision of Moore as to be a new work.[80]

80. A satisfactory brief source of information on Bowditch's work is found in a publication of the Peabody Museum, Salem, *A Catalogue of a Special Exhibition of Manuscripts, Books, Portraits and Personal Relics of Nathaniel Bowditch (1773–1838) with a Sketch of the Life of Nathaniel Bowditch by Dr. Harold Bowditch and an Essay on the Scientific Achievements of Nathaniel Bowditch, with a Bibliography of his Publications by Professor Raymond Clare Archibald* (Salem, Mass., 1937). Professor Archibald's sketch and bibliography are important extensions of his article on Bowditch in the *Dictionary of American Biography.* An interesting brief article is *Nathaniel Bowditch* Peabody Museum (Salem, Mass., 1945), reprinted

The careful study of this evolution from Moore to Bowditch, sometimes not well understood, at once clears away a serious misapprehension, namely that Bowditch himself was the inventor of all the methods his book proposes and the maker of its elaborate tables. Nothing could be less true. Bowditch was simply one, though a brilliant one, in a long line of writers who had been at work on the subject for some three centuries. He revised and added to Moore, who himself had revised John Robertson's work, first published in 1750.[81] Through the centuries from the *Regimento do estrolabio* of 1509, men through successive generations had each been taking up where the other left off, retaining the good, discarding the bad or the superfluous, adding new matter, revising, and clarifying until finally with Bowditch was attained a splendid summary of an age-long experiment. He stood at the end of a process rather than at the beginning. After him the great advances were to be based not upon new scientific principles but largely upon a succession of improvements in mechanical methods which, through immense complication of means, continue to simplify the actual processes of navigation.

Blunt brought out many editions of Bowditch's summary of human concern with the problems of safe sailing, and upon his retirement from business passed on the rights in the work to his sons. From them in 1866 the government bought the copyright and in 1868 took up the publication of the work in the general interest. Beginning where Bowditch left off, the United States Hydrographic Office has done to Bowditch what Bowditch did to Moore, revising, adding chapters, reorganizing, and so by ceaseless vigilance compelling the book to keep abreast of the newest and the best in a science which has never given over its contest with the elemental forces opposed to the ship at sea.

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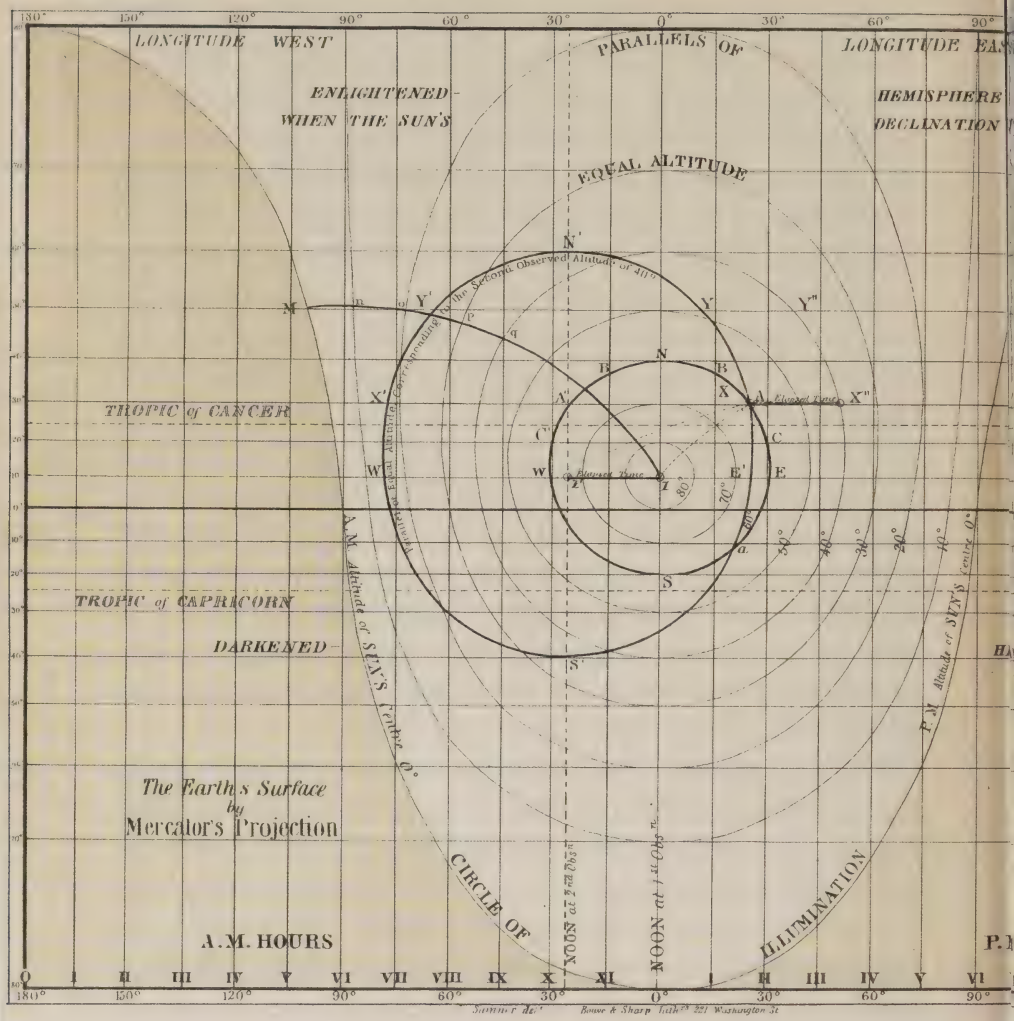
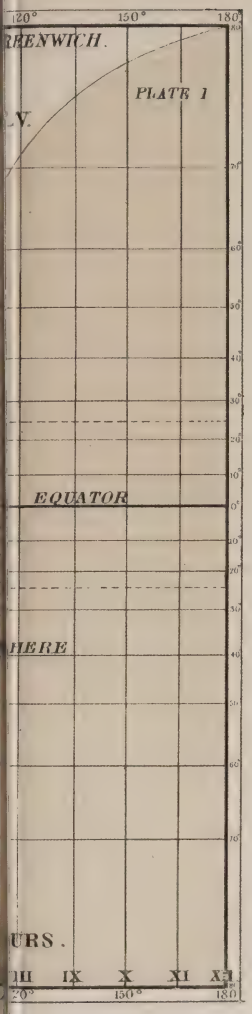
from *The American Neptune* v, No. 2, 1945. [see also, John F. Campbell, *History and Bibliography of 'The New American Practical Navigator' and the 'American Coast Pilot'* (Salem, Mass., 1964).

81. John Robertson, *Elements of Navigation.* 2 volumes. (London, 1750).



Thomas H. Sumner, an American sea captain, made the first major contribution in several centuries to the practice of celestial navigation with his *New and Accurate Method of Finding a Ship's Position at Sea* (Boston, Mass., 1843). In December 1837, while sailing from Charleston, South Carolina, to Greenock, Scotland, Sumner discovered a method of astronomical position-line



A

NEW AND ACCURATE METHOD

OF

FINDING A SHIP'S POSITION AT SEA,

BY PROJECTION ON MERCATOR'S CHART.

WHEN THE LATITUDE, LONGITUDE, AND APPARENT TIME AT THE SHIP ARE UNCERTAIN; ONE ALTITUDE OF THE SUN, WITH THE TRUE GREENWICH TIME, DETERMINES,

FIRST,

THE TRUE BEARING OF THE LAND;

SECONDLY,

THE ERRORS OF LONGITUDE BY CHRONOMETER,
CONSEQUENT TO ANY ERROR IN THE LATITUDE;

THIRDLY,

THE SUN'S TRUE AZIMUTH.

WHEN TWO ALTITUDES ARE OBSERVED, AND THE ELAPSED TIME NOTED, THE TRUE LATITUDE IS PROJECTED; AND IF THE TIMES BE NOTED BY CHRONOMETER, THE TRUE LONGITUDE IS ALSO PROJECTED AT THE SAME OPERATION.

The Principles of the Method being fully explained and illustrated by Problems, Examples, and Plates,

WITH RULES FOR PRACTICE, AND EXAMPLES FROM ACTUAL OBSERVATION.

BY CAPT. THOMAS H. SUMNER.

BOSTON:
PUBLISHED BY THOMAS GROOM & CO., 82 STATE STREET.
1843.

navigation by which he fixed a ship's position by taking cross-bearings on two or more celestial bodies. Sumner made known his discovery for the first time in his pamphlet. In 1875, a French naval officer, Marcq Sainte-Hilaire, introduced another approach, the *méthode du point rapproché* or the intercept method. *John Carter Brown Library.*

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